

**Annual Report for Period:** 07/2002 - 07/2003

**Submitted on:** 05/30/2003

**Principal Investigator:** Yarnal, Brenton M.

**Award ID:** 9978052

**Organization:** PA St U University Park

**Title:**

Infrastructure to Develop a Human-Environment Regional Observatory (HERO) Network

### Project Participants

#### Senior Personnel

**Name:** Yarnal, Brenton

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Knight, C. Gregory

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Easterling, William

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** MacEachren, Alan

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Gahegan, Mark

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Liverman, Diana

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Liverman shares oversight of the SOMBRHERO project and is in charge of human-environment methodology development, including community assessment and vulnerability index creation.

**Name:** Turner, Billie

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Turner guides the overall direction of HERO-CM, secures institutional support, and conducts and directs research on global change in local places.

**Name:** White, Stephen

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

White is examining population redistribution, socio-economic drivers, and other exogenous and endogenous agents of change in southwestern Kansas.

**Name:** Comrie, Andrew

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Comrie shares oversight of the SOMBRHERO project and is in charge of environmental analyses, including data set development and analyses of climate and geospatial information.

**Name:** Harrington, John

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

John Harrington is examining links between climate variations and land use and land cover change and is serving as the local organizer for HPO-HERO activities.

**Name:** Goodin, Douglas

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Goodin is working on remote sensing of land-cover change and assisting with the assessment of climatic variability.

**Name:** Harrington, Lisa

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Lisa Harrington is looking at local measures of vulnerability, public opinion, and local perceptions of environmental change.

**Name:** Kromm, David

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Kromm is assessing the importance of resource availability, irrigation technology changes, and agricultural policy on land use change.

**Name:** Lu, Max

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Lu is looking at changes in the cattle feedlot industry and examining social and demographic measures of local change.

**Name:** Merideth, Robert

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Merideth advises on bi-national environment and policy research and provides links to other ongoing projects and stakeholders in the region.

**Name:** Pontius, Robert

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Pontius is leading the 2001-2002 HERO Fellows Program and overseeing the LCLUC research of HERO-CM using GIS and statistical models.

**Name:** Varady, Robert

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Varady advises on environmental policy and environmental conflict resolution in the border region and in the Southwest and

decision-makers.

**Name:** Loveland, Thomas

**Worked for more than 160 Hours:** No

**Contribution to Project:**

USGS employee who supervises Rachel Clement at EROS Data Center. Arranged for Ms. Clement to attend Penn State to earn Ph.D. and to participate in HERO project. Participates in all-hands meetings and joins in other HERO activities when opportunity allows.

**Post-doc**

**Name:** Diem, Jeremy

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Diem carried out geospatial environmental and social data library development, a vulnerability index review, and SOMBRHERO workshop organization.

**Name:** Chen, Ke

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Chen is in charge of day-to-day project management of HERO-CM, coordinates HERO and HERO-CM activities in consultation with lead faculty, and carries out research for HERO-CM focusing on institutional and informational dimensions of regional sustainable development.

**Name:** Tran, Liem

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Tran concentrated on geocomputation, developing tools for knowledge discovery. He also designed a conceptual framework for a knowledge discovery system.

**Name:** Wu, Shuang-Ye

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Wu helped to develop the vulnerability protocol and then she implemented it. She also conceptualized the integrated regional assessment of LULCC.

**Name:** Sorrensen, Cynthia

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Ahlqvist, Ola

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Ahlqvist is working on concept representation strategies for HEROINE's knowledge management effort, particularly on certainty and confidence measures for semantic information and the application of rough sets in computing agreement between different constructions of geographic concepts.

**Name:** Neff, Robert

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Neff helps with day-to-day project management of the SRB-HERO, coordinates HERO and SRB-HERO activities in consultation with lead faculty, and carries out research for SRB-HERO. Specifically, he is the moderator of the vulnerability and REU working

vulnerability research. He is also working to develop protocols for Greenhouse Gas emission inventories and mitigation plans.

## Graduate Student

**Name:** Brewer, Isaac

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Brewer developed the HERO Website and logo; he is building the geocollaboratory tool for the Website. He is located in Hanford, Washington for the summer where he is working with the collaboratory development team at Pacific Northwest National Laboratory.

**Name:** Guo, Diansheng

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Guo is working on developing the capability to build links between the database and Web applications in geovisualization, geocomputation, and geocollaboratory.

**Name:** Leduc, Stephen

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Leduc's primary work focused on developing the computer-based Delphi tool.

**Name:** Rose-Redwood, Reuben

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Rose-Redwood assembled the SRB and Spring Creek Watershed databases.

**Name:** Williams, Craig

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Williams helped with Website development and maintenance, plus graphical support for the project.

**Name:** Wood, James

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Wood compiled data sources on LULC in the southwest Kansas study area. He is now examining relationships between climate variability and land-use change.

**Name:** Clement, Rachel

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Geddes, Alistair

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Pike, William

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Yu, Chaoqing

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Gao, Hong

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Van Looy, Jeffrey

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** McEachern, Menzie

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Baskaran, Latha

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Baskaran is helping with a case study on LULCC in the Centre county aimed at developing protocols for the collection of socioeconomic data in the context of LULCC change. She collects and analyzes data, and is writing a paper at the moment related to LULCC in Centre County in the last 30-40 years.

**Name:** Kroemer, Ryan

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Ryan helped mentor the summer REU students (GIS support) and is working on LUCC doing digital image processing of Landsat data.

**Name:** Luo, Junyan

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Luo's research concerns the development of software tools that coordinate the interaction of Java components by modeling their behavior in ontologies. This coordination aids the integration of components created by different developers, and assists novice users in correctly linking components to suit an analysis task. Luo contributes to the HEROINE team's work on describing the conceptual information associated with electronic resources and collaborates on software development.

**Name:** Reker, Ryan

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Ryan is assisting with the analysis of land cover change and plans to do his thesis on LUCC changes associated with the CRP program.

**Name:** Chen, Hao

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

#### Undergraduate Student

**Name:** Frost, Ethan

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Hecht, Jory

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Malanson, Jeffrey

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Stratton, Samuel

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Menda, Tim

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Born, Beate

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Malizia, Nick

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Morris, Patrick

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Wang, Hua

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Spangler, Jason

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Spangler is helping develop HERO products for publication, and will be assisting with research linked to the vulnerability protocol.

**Name:** Sweet, Ebony

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Wood, Stacia

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

#### **Technician, Programmer**

**Name:** Gutowski, Martin

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Gutowski helped develop the Oracle database for HERO and the tagging system for the datasets.

**Other Participant**

**Name:** Kirtland, David

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Kirtland coordinates the collaboration between USGS and HERO.

**Research Experience for Undergraduates**

**Name:** Brendle, Anna

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Years of schooling completed:** Other

**Home Institution:** Same as Research Site

**Home Institution if Other:**

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2001

**REU Funding:** No Info

**Name:** Lindblad, Andrea

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Years of schooling completed:** Other

**Home Institution:** Other than Research Site

**Home Institution if Other:** University of Arizona

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2001

**REU Funding:** No Info

**Name:** O'Brien, Erin

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Years of schooling completed:** Other

**Home Institution:** Other than Research Site

**Home Institution if Other:** Kansas State University

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2001

**REU Funding:** No Info

**Name:** Shirk, Alissa

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Years of schooling completed:** Junior

**Home Institution:** Same as Research Site

**Home Institution if Other:**

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2001

**REU Funding:** No Info

**Name:** Shusas, Emily

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Years of schooling completed:** Other

**Home Institution:** Other than Research Site

**Home Institution if Other:** Clark University

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2001

**REU Funding:** No Info

**Name:** Bonanno, Brenda

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Her immediate plans are to go to Graduate school with the University of Arizona next fall (2003) and study links between alteration of the landscape and the proliferation of vector-borne diseases. Currently she is working full-time at Pima Association of Government, a non-profit non-governmental organization, as a project technical assistant. Pima Association of Government is the air quality and water quality planning agency for Pima County, Tucson, Arizona, and also manages the travel reduction program for the city.

**Years of schooling completed:** Other

**Home Institution:** Same as Research Site

**Home Institution if Other:**

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2002

**REU Funding:** REU supplement

**Name:** Freschenmeyer, Mark

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Freschenmeyer participated in the summer 2002 REU Site testing the vulnerability protocol.

**Years of schooling completed:** Other

**Home Institution:** Other than Research Site

**Home Institution if Other:** Pittsburg State University

**Home Institution Highest Degree Granted(in fields supported by NSF):** Master's Degree

**Fiscal year(s) REU Participant supported:** 2002

**REU Funding:** REU supplement

**Name:** Fuller, Sarah

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

In summer 2002, Fuller participated in the HERO REU site, doing her research at the SRB-HERO site. Sarah is currently working as an intern at the Chester County GIS Department. She is planning to further her education and is currently looking at graduate programs around the country. Her interests are mainly Urban/Environmental planning, she would like to research water resource management in urban areas, and water resource management issues in general.

**Years of schooling completed:** Junior

**Home Institution:** Same as Research Site

**Home Institution if Other:**



**Home Institution Highest Degree Granted(in fields supported by NSF):** Master's Degree

**Fiscal year(s) REU Participant supported:** 2002

**REU Funding:** REU supplement

**Name:** Hinojos, Sarah

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Hinojos brought GIS expertise to the 2002 summer REU Site. She has expressed interest in going on to graduate school and pursuing a research career.

**Years of schooling completed:** Junior

**Home Institution:** Other than Research Site

**Home Institution if Other:** Fort Hays State University

**Home Institution Highest Degree Granted(in fields supported by NSF):** Master's Degree

**Fiscal year(s) REU Participant supported:** 2002

**REU Funding:** REU supplement

**Name:** Mohr, Jamie

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Jamie recently enrolled at Clark as a transfer student. Jamie is currently employed in The George Perkins Marsh Institute at Clark University as an REU fellow, continuing the research she started this summer in vulnerability to Climate Change. After continuing her education to earn a MA in ecology, Jamie hopes to secure a position in environmental consulting.

**Years of schooling completed:** Sophomore

**Home Institution:** Same as Research Site

**Home Institution if Other:**

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2002

**REU Funding:** REU supplement

**Name:** Murray, Lucas

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Murray participated in the summer 2002 REU Site testing the vulnerability protocol.

**Years of schooling completed:** Junior

**Home Institution:** Same as Research Site

**Home Institution if Other:**

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2002

**REU Funding:** REU supplement

**Name:** Greg, Reiter

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Reiter participated in the summer 2002 REU Site testing the vulnerability protocol.

**Years of schooling completed:** Other

**Home Institution:** Same as Research Site

**Home Institution if Other:**

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2002

**REU Funding:** REU supplement

**Name:** Schifano, Jessica

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Schifano participated in the summer 2002 REU Site testing the vulnerability protocol.

**Years of schooling completed:** Other

**Home Institution:** Same as Research Site

**Home Institution if Other:** Worchester Polytechnic Institute

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2002

**REU Funding:** REU supplement

**Name:** Van Eman, Emily

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Participated in the 2002 summer REU Site. She has work experience in KSU's Geographic Information Systems Spatial Analysis Laboratory (GISSAL). Emily has also done some hourly undergraduate work on the Kansas HERO project this semester.

**Years of schooling completed:** Junior

**Home Institution:** Same as Research Site

**Home Institution if Other:**

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2002

**REU Funding:** REU supplement

**Name:** Weaver, Steve

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Steve is currently employed by the HERO project as an undergraduate research assistant, continuing his research from the summer and adding considerable value to existing HERO research. He is lead author on a forthcoming journal article describing a vulnerability assessment for the Spring Creek watershed. As part of this effort, Steve is working closely with HERO faculty and staff and Anna Brendle, a former REU Supplement student at Penn State who based her honors thesis on the Spring Creek Assessment. Steve is in the process of applying to graduate programs in Geography, with a focus in Human Dimensions of Global Environmental Change.

**Years of schooling completed:** Other

**Home Institution:** Same as Research Site

**Home Institution if Other:**

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2003 2002

**REU Funding:** REU supplement

**Name:** Windle, Bill

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Windle participated in the 2002 REU Site, and is considering graduate school as an option. He is also exploring employment opportunities within the state department that are well-suited to his geographic skills and knowledge

**Years of schooling completed:** Junior

**Home Institution:** Other than Research Site

**Home Institution if Other:** Bucknell University

**Home Institution Highest Degree Granted(in fields supported by NSF):** Bachelor's Degree

**Fiscal year(s) REU Participant supported:** 2002

**REU Funding:** REU supplement

**Organizational Partners**

**Clark University**

Clark University is the home of HERO-CM (Central Massachusetts).

**Kansas State University**

Kansas State University is the home of the High Plains-Ogallala (HPO) HERO.

**University of Arizona**

University of Arizona is home of the Southwest and Mexico Border Region HERO (SOMBRHERO).

**USGS****Pacific Northwest National Laboratory**

PNNL's Collaboratory Project is sharing electronic notebook technology with HEROINE to extend to specific human-environment applications. HEROINE investigators also are working with PNNL's Information Visualization Group. Both groups are hosting (and paying for) one of our senior graduate students to work with their staff during summer 2001.

**Harvard University**

Harvard donated the time of post-doctoral scholar Colin Polsky, who attended two all-hands meetings and provided feedback on continuing protocol development. In addition, Dr. Polsky co-hosted a workshop at Harvard directed at collaboration on methods for understanding vulnerability to climate change. This workshop was attended by Rob Neff, the research associate at the central office and has resulted in at least one collaborative journal article, in the final stages of preparation.

**Other Collaborators or Contacts**

As detailed in the report, we have had dozens of contacts—too many to list here. Three are significant:

- (1) The international Land Use Land Cover (LUCC) project. HERO has become an endorsed project in that IGBP-IHDP sponsored umbrella project.
- (2) The NSF-sponsored Long-Term Ecological Research (LTER) network. HERO is helping them plan the infrastructure to allow them to add a social science component to that biophysically based network.
- (3) The Sustainability Geoscope, which is part of the Potsdam Institute for Climate Impact Research (PIK) and funded by the German government. HERO is helping them plan the Geoscope—especially its infrastructure.

**Activities and Findings**

**Research and Education Activities:** (See PDF version submitted by PI at the end of the report)

**Findings:** (See PDF version submitted by PI at the end of the report)

**Training and Development:**

Faculty, post-doctoral researchers, graduate students, undergraduate students, and others worked on HERO in Year 3. Various combinations of funds from HERO and related projects supported these individuals. In some cases, students contributed their time without financial support. Whatever the circumstances, these arrangements provided HERO with valuable help and, at the same time, supported student academic programs.

An increasingly important focus for HERO is research participation by undergraduates. In Year 1, HERO applied for and received an NSF

Research Experiences for Undergraduates (REU) Supplement. This supplement supported the activities of five women undergraduates—two at Penn State and one each at Clark, Kansas State, and Arizona. Four were Honors students and the fifth was a McNair Scholar. Four students presented illustrated papers at the Annual Meeting of the Association of American Geographers in Los Angeles.

In addition to the HERO REU Supplement, HERO-CM maintained its own undergraduate HERO-CM Fellowship Program. Six undergraduate students (one of whom was supported on the HERO REU Supplement) were chosen from a pool of highly qualified applicants after a campus-wide recruitment campaign. Working with project staff and faculty mentors, they are contributing to the development of the data and informational infrastructure of HERO-CM in conjunction with their individual and/or team research projects. They also will help the HERO-CM team establish and test protocols that permit data sharing and site comparisons among the HERO sites. A core effort of HERO-CM, this program will continue annually.

Spurred by the success of the HERO REU Supplement and HERO-CM efforts, HERO developed an REU Site. HERO devoted a considerable portion of its spring activities to prepare for the HERO REU Site. Twelve students—three each from Massachusetts, Pennsylvania, Kansas, and Arizona universities—attended a two-week short course at which they received training in the theory and method of integrated regional assessment in general and vulnerability assessment in particular. After that, the students returned to their respective HEROs to apply the vulnerability assessment protocol, thereby testing the protocol and suggesting improvements to it. The three-person student teams not only collaborated with their mentors and colleagues at the four HEROs, but also interacted with the other REU students through the collaboratory. The highlight of the student collaboratory was weekly—and sometimes daily—videoconferences. NSF funded this highly innovative, distributed REU Site for one year and has since granted funding for an additional three years based on the success of this one-year pilot.

## University Faculty

### Principal Investigator

Brent Yarnal, Professor of Geography and Director of the Center for Integrated Regional Assessment, Penn State. Yarnal's primary responsibilities are to direct overall project and SRB-HERO activities, to lead the all-HERO network-building activities, to oversee development of the vulnerability assessment protocol, and to run the HERO REU Site.

### Co-Principal Investigators

William Easterling, Professor of Geography and Director of the Penn State Environmental Consortium, Penn State. In Year 2, Easterling led the SRB-HERO effort in scale interaction and land-use change, especially as they relate to carbon fluxes. His duties as Director of the Environmental Consortium required him to resign from HERO in Spring 2002.

Mark Gahegan, Professor of Geography and Associate Director of the GeoVISTA Center, Penn State. Gahegan is in charge of developing HEROINE database protocols, geocomputational methodologies, and GeoVISTA Studio.

C. Gregory Knight, Professor of Geography, Penn State. Knight is directing the SRB-HERO work on water resource/hydrologic vulnerability to climate and land-use change.

Diana Liverman, Professor of Geography, University of Arizona. In Year 2, Liverman shared oversight of the SOMBRHERO project and was in charge of human-environment methodology development, including community assessment and vulnerability index creation. During Year 3, she was Interim Dean of the College of Social and Behavioral Sciences and had limited input to HERO. Andrew Comrie directed SOMBRHERO activities in her absence.

Alan MacEachren, Professor of Geography and Director of the GeoVISTA Center, Penn State. MacEachren is overseeing the HEROINE geocollaboratory, Website development, and visualization efforts.

Billie Lee Turner II, Professor of Geography, Clark University. Turner guides the overall direction of HERO-CM, secures institutional support, and conducts and directs research on global change in local places.

Stephen White, Professor of Geography, Kansas State University. Until Year 2, White examined population redistribution, socio-economic drivers, and other exogenous and endogenous agents of change in southwestern Kansas. Midway through Year 2, he became Interim Dean of the College of Arts and Sciences and had limited input to HERO. John Harrington has directed CPO-HERO activities in his absence.

## Investigators

Andrew Comrie, Associate Professor of Geography, University of Arizona. Comrie shared oversight of the SOMBRHERO site in Year 2; in Year 3, he oversaw the site in Diana Liverman's absence. His primary responsibilities include environmental analysis, including data set development and analysis of climate and geospatial information.

Douglas Goodin, Associate Professor of Geography, Kansas State University. Goodin is working on remote sensing of land-cover change and assisting with the assessment of climatic variability.

John Harrington, Professor of Geography, Kansas State University. Harrington is directing CPO-HERO activities for Steven White. His main research tasks include examining links between climate variations and land use and land cover change.

Lisa Harrington, Associate Professor of Geography, Kansas State University. Harrington is looking at local measures of vulnerability, public opinion, and local perceptions of environmental change. She is the designated mentor for the HERO REU Site students.

David Kromm, Emeritus Professor of Geography, Kansas State University. Kromm is assessing the importance of resource availability, irrigation technology changes, and agricultural policy on land use change.

Max Lu, Assistant Professor of Geography, Kansas State University. Lu is looking at changes in the cattle feedlot industry and examining social and demographic measures of local change.

Robert Merideth, Assistant Director, Udall Center for Studies in Public Policy, The University of Arizona. Merideth advises on bi-national environment and policy research and provides links to other ongoing projects and stakeholders in the region.

Robert Gilmore Pontius, Assistant Professor of Geography, Clark University. Pontius is leading Clark's HERO Fellows Program, including the mentoring of the HERO REU students. He also conducts LUCC research at HERO-CM using GIS and statistical models. He is leading the all-HERO LUCC data storage and analysis efforts.

Robert Varady, Deputy Director, Udall Center for Studies in Public Policy, The University of Arizona. Varady advises on environmental policy and environmental conflict resolution in the border region and in the Southwest and provides connections to regional and local communities of decision-makers.

#### Post-Doctoral Research Associates

Ola Ahlqvist, Ph.D. 2001, Stockholm University. Postdoctoral Research Associate, Penn State. Ahlqvist is working on concept representation strategies for HEROINE's knowledge management effort, particularly on certainty and confidence measures for semantic information and the application of rough sets in computing agreement between different constructions of geographic concepts.

Jeremy Diem, Ph.D. 2000, Postdoctoral Research Associate, University of Arizona (50% of his support came from HERO/SOMBRHERO). Diem carried out geospatial environmental and social data library development, a vulnerability index review, and SOMBRHERO workshop organization in Year 1 and the beginning of Year 2. He is now a faculty member at Georgia State University.

Ke Chen, Ph.D., 1998, University of Western Michigan (HERO-CM; 100% of his support comes from HERO). Chen is in charge of day-to-day project management of HERO-CM, coordinates HERO and HERO-CM activities in consultation with lead faculty, and carries out research for HERO-CM focusing on institutional and informational dimensions of regional sustainable development.

Robert Neff, Ph.D. Expected, 2003, The Pennsylvania State University (SRB-HERO; 100% of his support comes from HERO). Neff helps with day-to-day project management of the SRB-HERO, coordinates HERO and SRB-HERO activities in consultation with lead faculty, and carries out research for SRB-HERO. Specifically, he is the moderator of the vulnerability and REU working groups, and is contributing to protocol and metaprotocol development, through both theoretical contributions and applied vulnerability research. He is also working to develop protocols for Greenhouse Gas emission inventories and mitigation plans.

Cynthia Sorrensen, Ph.D. 1998, Ohio State University; Assistant Social Research Scientist, University of Arizona. Sorrensen came to the project in August 2001 from California State University, Los Angeles where she was an Assistant Professor. She is in charge of overall management of the SOMBRHERO project and is the lead on setting the research agenda at SOMBRHERO that focuses on impacts of drought and climate change and water resources, vegetation, and fire hazard.

Liem Tran, Ph.D. 1999, University of Hawaii (SRB-HERO; varying levels of his support comes from HERO). Tran worked with Shuang-Ye

Wu on designing a meta-protocol and with Gil Pontius and others to develop protocol data requirements. He also initiated research on local decision-making and development that links quantitative and qualitative data collection and analysis.

Shuang-Ye Wu, Ph.D. 2000, Cambridge University (SRB-HERO; 50% of her support came in Year 1; 100% of her support came from HERO in Year 2; she is now an environmental consultant in the Washington, DC area). Wu helped develop the vulnerability assessment protocol, design a meta-protocol with Liem Tran, and develop and teach methodology modules for the HERO REU short course. She contributed to logistical support for the HERO REU Site.

#### Graduate Research Assistants

Latha Baskaran, M.S. student, Penn State (support from EPA). Baskaran is helping with a case study on LULCC in the Centre county aimed at developing protocols for the collection of socioeconomic data in the context of LULCC change. She collects and analyzes data, and is writing a paper at the moment related to LULCC in Centre County in the last 30-40 years.

Isaac Brewer, Ph.D. student, Penn State (academic year support from research sponsored by the GeoVISTA Center, summer support from HERO). Brewer worked at PNNL on the e-Notebook, making it an important part of the HERO collaboratory tool for the Website. During the academic year, he contributed to HERO without compensation, helping with e-Notebook, e-Delphi, and Web-based videoconferencing. He contributed to logistical support for the HERO REU Site.

Rachel Clement, Ph.D. student, Penn State (tuition paid by HERO; all other support from USGS). Clement is a USGS employee assigned to HERO for the two years needed to fulfill residency requirements in Penn State's Ph.D. program in Geography. She is working on land-use/land-cover and remote sensing analysis of the SRB-HERO. She contributed to logistical support for the HERO REU Site.

Hong Gao, M.A. student, Kansas State University (100% support from HERO). Gao compiled social, demographic, and agricultural census data for the 19 county HPO-HERO area.

Ryan Kroemer, GIScience Grad Certificate student, Kansas State University (100% support from HERO). Ryan helped mentor the summer REU students (GIS support) and is working on LUCC doing digital image processing of Landsat data.

Junyan Luo, Ph.D. student, Penn State. Luo's research concerns the development of software tools that coordinate the interaction of Java components by modeling their behavior in ontologies. This coordination aids the integration of components created by different developers, and assists novice users in correctly linking components to suit an analysis task. Luo contributes to the HEROINE team's work on describing the conceptual information associated with electronic resources and collaborates on software development.

Menzie McEachern, Ph.D. student, Clark (supported by NSF-funded Center for the Integrated Study of the Human Dimensions of Global Environmental Change at Carnegie Mellon University). McEachern worked for the HERO-CM Fellowship Program as support staff in summer and as Teaching Assistant to the yearlong HERO course in fall and spring.

William Pike, M.S./Ph.D. student, Penn State (summer and fall support 2002, and spring 2003 from HERO; contributed time in spring 2002). Pike mentored the HERO REU Supplement students during summer 2001 and helped build the SRB-HERO database. During Academic Year 2001-2002, Pike built the e-Delphi component of the collaboratory. He is currently improving e-Delphi and developing the knowledge management tool. He contributed to logistical support for the HERO REU Site.

Ryan Reker, M.A. student, Kansas State University (50% support from HERO). Ryan is assisting with the analysis of land cover change and plans to do his thesis on LUCC changes associated with the CRP program.

James Wood, M.A. student, Kansas State University (100% support from HERO). Wood compiled data sources on LULC in the southwest Kansas study area. He is now examining relationships between climate variability and land-use change.

Chaoqing Yu, Ph.D. student, Penn State University (100% support from HERO). Yu maintains the HERO Website and e-Notebook. He coordinates HERO Web-based videoconferencing.

#### Research Experiences for Undergraduate (REU) Researchers

Anna Brendle, Geography Honors, Penn State. Brendle applied the vulnerability assessment protocol to the Spring Creek Watershed. During

late spring and summer 2002, she helped develop the formal vulnerability assessment protocol and peer-mentored the Penn State REU students.

Brenda Bonanno, B.A. 2002, Geography and Psychology, University of Arizona. Her immediate plans are to go to Graduate school with the University of Arizona next fall (2003) and study links between alteration of the landscape and the proliferation of vector-borne diseases. Currently she is working full-time at Pima Association of Government, a non-profit non-governmental organization, as a project technical assistant. Pima Association of Government is the air quality and water quality planning agency for Pima County, Tucson, Arizona, and also manages the travel reduction program for the city.

Mark Freschenmeyer, Pittsburg State University, Kansas. Freschenmeyer participated in the summer 2002 REU Site testing the vulnerability protocol.

Sarah Fuller, B.A. Geography and Planning, Gamma Theta Upsilon, West Chester University 2002. In summer 2002, Fuller participated in the HERO REU site, doing her research at the SRB-HERO site. Sarah is currently working as an intern at the Chester County GIS Department. She is planning to further her education and is currently looking at graduate programs around the country. Her interests are mainly Urban/Environmental planning, she would like to research water resource management in urban areas, and water resource management issues in general.

Sarah Hinojos, B.S. Geography, Fort Hays State University, Kansas. Hinojos brought GIS expertise to the 2002 summer REU Site. She has expressed interest in going on to graduate school and pursuing a research career.

Jeffrey Malanson, Geography, Clark University. Malanson participated in the summer 2002 REU Site, and continues to work with researchers at Clark University on LUCC research.

Jamie Mohr, Environmental Science and Policy with a minor in Geography, Clark. Jamie recently enrolled at Clark as a transfer student. Jamie is currently employed in The George Perkins Marsh Institute at Clark University as an REU fellow, continuing the research she started this summer in vulnerability to Climate Change. After continuing her education to earn a MA in ecology, Jamie hopes to secure a position in environmental consulting.

Lucas Murray, Geography, University of Arizona. Murray participated in the summer 2002 REU Site testing the vulnerability protocol.

Greg Reiter, Geography, University of Arizona. Reiter participated in the summer 2002 REU Site testing the vulnerability protocol.

Jessica Schifano, Biotechnology and Public Policy, Worcester Polytechnic Institute. Schifano participated in the summer 2002 REU Site testing the vulnerability protocol.

Emily Van Eman, Geography, Kansas State University. Participated in the 2002 summer REU Site. She has work experience in KSU's Geographic Information Systems Spatial Analysis Laboratory (GISSAL). Emily has also done some hourly undergraduate work on the Kansas HERO project this semester.

Steve Weaver, Geography, Penn State. Steve is currently employed by the HERO project as a research assistant, continuing his research from the summer and adding considerable value to existing HERO research. He is the coordinating author on a forthcoming journal article describing a vulnerability assessment for the Spring Creek watershed. As part of this effort, Steve is working closely with HERO faculty and staff and Anna Brendle, a former REU Supplement student at Penn State who based her honors thesis on the Spring Creek Assessment. Steve has accepted an offer to work on a Masters Degree at the Penn State Geography Department, and will continue to be engaged in HERO research.

Bill Windle, Geography, Bucknell University. Windle participated in the 2002 REU Site, and is considering graduate school as an option. He is also exploring employment opportunities within the state department that are well-suited to his geographic skills and knowledge

#### HERO-CM Undergraduate Research Fellows

HERO-CM also sponsors an annual Undergraduate Fellows program in which students develop expertise with the hardware, software, and data available in Clark University's CoFERT (Computing Facility for Environmental Research & Training). The disciplines and research topics of the 2001-2002 Fellows were:

- ò Nick Malizia (Geography, Clark University) Water Quality and Hydrology
- ò Patrick Morris (Geography, Clark University) LUCC

ò Hua Wang (Human Ecology, College of the Atlantic) Energy and GHG Emissions

#### Other Undergraduate Researchers

Jason Spangler, Geography, Penn State (SRB-HERO support). Spangler is helping develop HERO products for publication, and will be assisting with research linked to the vulnerability protocol.

#### Other Investigators

David Kirtland, USGS, USGS Global Change Research Program, Reston, Virginia. Kirtland coordinates the collaboration between USGS and HERO.

Thomas Loveland, USGS, EROS Data Center, Sioux Falls, South Dakota. Loveland is Principal Investigator on the Land Cover Trends project and chief link between USGS LUCC activities and HERO.

#### Outreach Activities:

##### Central Office Outreach

HERO made substantial progress towards the goal of developing an international network of researchers working on local human-environment interactions. In Year 1, network building concentrated on three activities, including Website development and interactions with the LUCC Programme and the nascent LTER social science community. Year 2 expanded on these three activities and added the Sustainability Geoscope to the network of partners.

Work continues on the HERO Website (<http://hero.geog.psu.edu>). The Year 1 annual report highlighted many of the design and implementation issues tackled in an effort to make the Website useful and useable. Year 2 saw the HERO REU Site component added to the Website, as well as several white papers on protocol development and elements of the collaboratory. Most important, the collaboratory portion of the Website grew, with additions of e-Delphi and e-Notebook.

Interaction with members of the LUCC Programme took place at international meetings, first in Amsterdam in July, then in Berlin in October. Additional communication took place in conjunction with land-use research at HERO-CM and SRB-HERO. It is anticipated that the LUCC Programme will start using the HERO e-Delphi tool soon.

HERO took part in biocomplexity incubation activities with the LTER social science network during Year 2. HERO personnel from HERO-CM and SRB-HERO took part in two workshops, one in Madison, Wisconsin aimed at LUCC modeling, and another in Phoenix, Arizona focused on analysis of demographic and historical data in human-environment research. One HERO researcher (Pontius) was co-organizer of the Madison workshop. The LTER social scientists are still in the planning, proposal-writing, and overview paper-writing stages, but participation in these activities will result in the adoption of HERO infrastructure for facilitating future network-wide interaction. An important Year 2 outreach activity involved the Sustainability Geoscope. Similar to HERO, Geoscope plans to develop an international network of sites monitoring local sustainability. HERO was fortunate to become involved with Geoscope as they began conceptualizing this network. Hence, it is likely that HERO infrastructure will be foundational to the Sustainability Geoscope.

Outreach continued during Year 3, including participating in a workshop on methodologies and vulnerability at Harvard, which was co-organized by Harvard and PIK. Colin Polsky, a workshop organizer working at Harvard, will be joining the HERO-CM team in Fall 2003 as a faculty member. The HERO team is also proposing a symposium for the 2004 Annual Meeting of the American Association for the Advancement of Science in Seattle. The symposium will engage investigators working on the local and regional dimensions of global environmental change from across the United States. In addition, the HERO Central office has received inquiries from developing countries regarding the availability of vulnerability protocols and has responded by sharing preliminary results and publications. We expect these relationships to continue to grow as the project progresses.

#### Outreach by HEROINE and the HEROs

HEROINE's outreach efforts during Year 3 took several forms. Through its Web-based tools, particularly e-Delphi, HEROINE made its products available to a global audience. As noted earlier, organizations around the world have requested access to the e-Delphi system, and HEROINE personnel are assisting in the development of their activities. Team members are also partnering with researchers in the GeoVISTA Center in the development of knowledge management tools, contributing expertise and software components to projects funded by NSF's Digital Government program, among other agencies.



HERO-CM is developing regional collaborations and partnerships with government agencies, research institutions, private sector organizations, and non-governmental organizations. These include the Massachusetts Geographic Information System (MASSGIS), Massachusetts Executive Office of Environmental Affairs, Massachusetts Department of Environmental Management, Massachusetts Department of Environmental Protection, Greater Worcester Land Trust, Massachusetts Audubon Society, Blackstone River Valley National Heritage Corridor, Quinebaug and Shetucket Rivers Valley National Heritage Corridor program, Massachusetts Institute for Social and Economic Research (MISER), Central Massachusetts Regional Planning Council, Central Massachusetts Regional Environmental Council (REC), Bureau of the Census (Regional Office), and New Ecology Incorporated. HERO-CM is asking these groups to contribute expertise to aspects of the project, to help train and supervise students, and to provide financial and in-kind support. HERO-CM also interacts with visiting scholars who show strong interest in HERO (e.g., Richard Rockwell, the leader of the Industrial Transformation Science Project of the International Human Dimensions Programme on Global Environmental Change [IHDP-IT]). Team members have participated in various activities organized by local environmental NGOs (such as the Tatnuck Watershed Association and REC). Most recently, the HERO-CM team was asked by the City of Worcester to perform a GIS analysis of the impact of brownfields in the area, demonstrating the relevance of its most recent data collection and analysis efforts. SRB-HERO investigators have worked on human dimensions of global change research in the SRB and the Mid-Atlantic Region for many years and, as a formal part of that research, have engaged in stakeholder outreach. At these spatial scales, their outreach efforts continue to touch literally dozens of institutions (including academe, federal government, state government, non-governmental environmental organizations, and corporations) and hundreds of individuals. The intensive investigation currently underway in Centre County, Pennsylvania, however, is causing SRB-HERO personnel to turn their attention to their own backyards. The SRB-HERO research is focusing the team on local NGOs, starting with the Spring Creek Watershed Community, ClearWater Conservancy, and Penns Valley Conservation Association. The team is starting to work closely with the Centre County Planning Department and the Planning Department of the Centre Region Council of Governments, as well as planners in the local townships and boroughs. Significant interaction on global environmental change issues is developing with Leadership Centre County, a group dedicated to developing local leaders. Links are being forged with Penn State's Department of Landscape Architecture, which runs both the Watershed Stewardship Program and the Hamer Center for Community Design Assistance, which focuses on providing education and technical assistance related to land use and transportation, community and economic development, the environment and quality of life to local communities. Ongoing ties to local community water systems and to local emergency management are being strengthened.

HPO-HERO researchers have a history of collaboration with federal, state, regional, and local organizations with interests in the economic, natural resource, and social viability of southwestern Kansas; the research team is working to expand the network. Examples of collaborative links related to water resources include USGS and the High Plains Regional Ground Water Study, the Kansas Geologic Survey and their Atlas of the Kansas High Plains Aquifer, and the Director of the Southwest Kansas Groundwater Management District Number 3. Another example involves LUCC mapping: HPO-HERO team members are working with Kansas Applied Remote Sensing (KARS) researchers on additional funded projects. KARS staff members have put together three different statewide satellite-based land-cover maps. Further, team members went to the study area twice during Fall 2002 Semester to attend local meetings dealing with possible state mandated changes in rules and regulations associated with the use of ground water. The team continues to be very interested in how internal and external voices help formulate policy that influences LUCC in the HPO-HERO area.

All of the SOMBRHERO Co-PIs have wide-ranging active research and professional agendas in the study region with broad relationships to SOMBRHERO. Team members have initiated and maintained affiliations with numerous governmental and non-governmental border groups working on human-environment issues (e.g., among many others, the North American Development Bank, the Border Environmental Cooperation Commission, and the Aurora Partnership, which focuses on the use of GIS and spatial decision-support systems and tools for environmental decision-making and management). They are also involved in a Dialogue on Water and Climate in the San Pedro River Basin, aimed at engaging stakeholders across the border into dialogue on water issues in the San Pedro watershed. They have also acquired a University of Arizona Faculty Small Grant to employ a geography graduate student in a pilot study to develop geovisualization techniques of the SOMBRHERO region. The student developed a border webpage to assess institutional links and a Web-atlas is forthcoming to facilitate visualization of SOMBRHERO research and results. We have worked with the Commission on Environmental Cooperation (CEC) in Montreal on a case study of transboundary water issues (i.e., hydrologic uncertainty, demand, institutional constraints, and water conflict) in the San Pedro and Santa Cruz river basins. A team member is Co-Chair of the Scientific Advisory Committee for the Inter-American Institute for Global Change. Another team member acquired a NASA Space Grant for Undergraduate Research to employ an undergraduate (Summer 2002 REU student Lucas Murray) through the academic year to work on dust pollution in the Nogales region. This work also contributes to the remote sensing work done on the Nogales region. Team members are part of another major human-environment research project, the Climate Impact Assessment for the Southwest (CLIMAS) funded by NOAA, which focuses on the greater Arizona-New Mexico region and surrounding areas including northern Mexico. While the CLIMAS concentrates on climate variability and forecasting, pertinent links to SOMBRHERO include downscaled climate data, climate and health analyses, and sectoral vulnerability studies (e.g., urban water, ranching, forest fire). One team member is finishing up a three year study on impacts of climate variability in the Brazilian Amazon funded by NOAA, which addresses issues of drought and vulnerability. Though in a completely different ecosystem, this work conceptually overlaps with SOMBRHERO research on vulnerability.

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### **Web/Internet Site**

**URL(s):**

<http://hero.geog.psu.edu>

**Description:**

This Website is a key element of HERO. It is an tool for collaboration among this project's investigators, it is the link between the investigators and other investigators beyond the project, and it is foundational to developing a national and worldwide network of human-environment researchers. It is will be under constant development and revision throughout the life of the project; i.e., it will always be "under construction." Home pages for individual HERO sites are linked from the main site. The individual HERO site URLs are:  
<http://www.u.arizona.edu/~csorren/sombrhero/>;  
<http://www.clarku.edu/departments/hero/index.shtml>;  
<http://www.ksu.edu/geography/research/hero.htm>.

### **Other Specific Products**

**Product Type:** Software (or netware)

**Product Description:**

GeoVISTA Studio offers Java-Based, visual programming. Beans of interest to sponsors or other researchers are made freely available. Further details can be found in Gahegan et al. (2002) and Takatsuka and Gahegan (2002). The environment, along with some of the tools developed in this research, can be downloaded over the Internet from <http://www.geovistastudio.psu.edu/jsp/index.jsp>. Studio code and applications are also now hosted on the SourceForge website (<http://sourceforge.net/projects/geovistastudio/>) for community development and free access.

**Sharing Information:**

Studio continues to go from strength to strength, and now has a significant user-base. Studio is also being used by another Digital Government group (Quality Graphics--DGQG), and by a number of federal agencies and universities (See outreach activities above). We plan to leverage additional resources to improve online training and documentation to make these tools available to a wider community of scientists.

**Product Type:** Software (or netware)

**Product Description:**

We are developing a Web-based geocollaboratory tool based on collaboratory tools developed by the Pacific Northwest National Laboratory's Collaboratory Project, one of our collaborators.

**Sharing Information:**

The geocollaboratory tool will be accessible to interested human-environment researcher groups at the HERO Website.

**Product Type:** Weekly electronic newsletter

**Product Description:**

Merideth, Robert, ed. AuroraNet News. Weekly electronic newsletter for the Aurora Partnership focused on the use of GIS and spatial decision-support systems and tools for environmental decisionmaking and management. <<http://www.aurorapartnership.org/AuroraNet.html>>.

**Sharing Information:**

Internet

**Product Type:** Software (or netware)

**Product Description:**

e-Delphi network, which supports group issue exploration, decision-making, and consensus building via an anonymous, moderated electronic Delphi process

**Sharing Information:**

Via the internet

**Product Type:** Software (or netware)**Product Description:**

Our work has resulted in three modules (Geomod, Validate, and ROC) in the latest version of the GIS software Idrisi.

**Sharing Information:**

Software is available through the GIS software Idrisi.

**Contributions****Contributions within Discipline:**

Although the principal disciplinary field of the HERO project is Geography, the project emphasizes research and education in two interdisciplinary fields that reach beyond the discipline: Geographic Information Science (GIScience) and Human Dimensions of Global Environmental Change (HDGEC). HERO is contributing to Geography through the development of GIScience and its application to human-environment problems, both of which are areas of prominence within the discipline. Geography is also benefiting because of the visibility that it is gaining from the leadership role that HERO is taking in the HDGEC research community and in the larger global change research community. HERO is contributing to the HDGEC research community through the HERO infrastructure, which includes the protocols for global change in local places research, the development of GIScience tools for use by the HDGEC research community, and the network building aimed at bringing HDGEC researchers together.

**Contributions to Other Disciplines:**

Other disciplines and areas of science are benefiting from HERO in two ways. First, human-environment studies are not a focus in most social science programs at NSF; they also tend to be secondary at other federal agencies. By developing a focus on human-environment studies and by building infrastructure to support these studies, HERO is turning the spotlight on this important, but neglected theme in modern social science and in agency missions. Second, the main ideas behind HERO (i.e., infrastructure to support complex environmental science, monitoring human-environment interactions, and global change in local places) appear to be gaining purchase in the larger global change research community. As the United States Global Change Research Program (USGCRP) discusses its future role in American science and society, the ideas behind HERO come up repeatedly as ideals to target. Even if HERO does not itself extend beyond the initial five years of the project, it appears that its ideas might.

**Contributions to Human Resource Development:**

On the one hand, HERO is developing a cadre of scientists imbued with knowledge about global change in local places and who know how to apply GIScience to solving these human-environment problems. On the other hand, HERO is helping scientists interested in GIScience to advance that science and, at the same time, to become familiar with human-environment problems. Furthermore, HERO is doing these things with a diverse group of undergraduate, graduate, and post-doctoral students, as well as professional staff and faculty. HERO investigators have included 20 women and 12 minority researchers (30% and 18%, respectively, of all participants in the project). The upcoming HERO REU Site will include eight women and two minorities.

**Contributions to Resources for Research and Education:**

HERO is an infrastructural development project, so the emphasis is less on producing scientific findings and journal articles reflecting these findings and more on generating physical, institutional, and information resources for scientists and students. Although infrastructure takes time to build, these products from HERO are maturing, in use by the investigators, and in use by researchers outside HERO.

**Contributions Beyond Science and Engineering:**

If the vision pans out, HERO infrastructure will help make it possible for scientists and decision-makers to understand the consequences of global environmental change on people and places, as well as how that people and places contribute to global environmental change. Such understanding will enable informed local action and policy to facilitate that action.

**Special Requirements**

**Special reporting requirements:** None

**Change in Objectives or Scope:** None

**Unobligated funds:** less than 20 percent of current funds

**Animal, Human Subjects, Biohazards:** None

**Categories for which nothing is reported:**



# INFRASTRUCTURE TO DEVELOP A HUMAN-ENVIRONMENT REGIONAL OBSERVATORY (HERO) NETWORK

## 2003 Annual Report

May 30, 2003



Supported by the National Science Foundation Grant SBE 9978052, with additional support from the Office of Global Programs of the National Oceanic and Atmospheric Administration



## PROJECT ACTIVITIES

### Goal and Strategies

Scientists and policy makers now realize that localities will play a central role in addressing the causes and consequences of global environmental change. For example, to mitigate global greenhouse gas emissions, national governments will take actions at specific places (such as cutting point-source emissions from manufacturing processes) or across small regions (such as managing forests to maximize carbon sequestration). At the same time, people will experience the positive and negative impacts of climate change locally and will implement adaptation strategies locally.

Despite this awareness, science has no systematic effort to monitor global environmental change and related human-environment interactions at local scales. One reason is that infrastructure does not exist that allows and promotes such monitoring.

Consequently, the goal of the Human-Environment Regional Observatory project (HERO) is to develop the infrastructure needed to monitor and understand the local dimensions of global environmental change, with emphasis on human-environment interactions. To reach that goal, the project has four strategies. First, HERO is developing research protocols and data standards for collecting data. These protocols and standards will facilitate the studying and monitoring of human-environment interactions at individual sites and, at the same time, will enable cross-site comparisons and generalizations. Second, HERO is building a Web-based networking environment that will help investigators share data, analyses, and ideas from remote locations. Third, HERO is field-testing these concepts by applying the protocols, standards, and networking environment in diverse biophysical and socioeconomic settings. Finally, HERO is organizing a network of researchers who are investigating the local dimensions of global environmental change and who will use the HERO infrastructure.

### Research Design

The research design comes directly from the strategies outlined above and has three components. The first component is the Web-based HERO Intelligent Networking Environment (**HEROINE**), which has four ongoing tasks. The first is to develop methods for handling the heterogeneous quantitative and qualitative, biophysical and socioeconomic data generated in local human-environment research. The second is to develop innovative geocomputational techniques to analyze these diverse data. The third is to develop ways to visualize these heterogeneous data and analyses. The fourth is to build a geocollaboratory where researchers from around the world can share, analyze, visualize, and compare those data, interacting with one another while working at their personal computers or in small conference rooms.

The second component of the HERO research design consists of proof-of-concept testing. To provide a real-world context for developing the infrastructure, testing focuses on the question, “How does changing land use affect the vulnerability of people and places to hydroclimatic variation and change?” HERO is addressing this question at four HERO proof-of-concept testing sites (**HEROs**) in diverse biophysical and socioeconomic settings. Researchers from

these HEROs are collecting data using the same protocols, storing and sharing the data using the same data standards, analyzing and visualizing the data using the same geocomputation and visualization tools, and interacting through the HERO collaboratory. An important part of this interaction is to use the collaboratory to develop the protocols, standards, and tools through computer-assisted group decision-support techniques (e.g., the Delphi method).

For the third component of the research design, HERO is striving to build a network of researchers working on the local dimensions of environmental change. As a starting point, HERO has developed relationships with three consortia of human-environment researchers. One consortium is the international Land Use/Land Cover Change (LUCC) Programme, a Programme Element of the International Human Dimensions Programme (IHDP) and the International Geosphere-Biosphere Programme (IGBP). The second consortium involves the US Long-Term Ecological Research (LTER) Network funded by NSF, which is adding a social science component to its ongoing biophysical monitoring and research. The third consortium is the incipient Sustainability Geoscope, an initiative of the Potsdam Institute for Climate Impact Research (PIK) that is funded by the German government. Much like HERO, Geoscope aims to develop an international network of sites monitoring local sustainability. HERO is treating LUCC, LTER, Geoscope, and other research and monitoring sites as a stakeholder network, simultaneously linking them through the HERO infrastructure and working with them to develop infrastructure that meets their needs.

## **All-HERO Activities**

HERO is a collaborative project linking the four HEROs, HEROINE, and USGS partners. Four clusters of activities engaged the entire HERO team in Year 3: all-hands meetings, intensified cross-site collaboration aided by collaboratory tools, special sessions and poster and paper presentations at the Annual Meeting of the Association of American Geographers, and undergraduate research.

Three all-hands meetings connected team members. The first was a two-and-a-half-day all-hands meeting held at Penn State in June 2002. This meeting took place at the end of a two-week Research Experience for Undergraduate (REU; see below) training course involving undergraduate researchers from all four HERO sites. The faculty mentors from each HERO joined their undergraduate students, who were included in all aspects of the all-hands meeting, while other members of the HERO team joined the meeting via video and phone conferences from as far away as England. Activities included updates from each HERO and HEROINE, discussion of short-term research goals for the REU site (see below), discussion of future research plans, a field trip to part of the Susquehanna River Basin HERO study area, and planning for future meetings. The field trip gave researchers from the other HEROs an opportunity to get to know the Penn State study area and compare and contrast it with their own. It also served as an informal setting for important discussions about collaboration. In addition, formal meetings included a much larger group of HERO researchers through video conferencing and allowed the team as a whole to continue to develop its research agenda.

A second all-hands meeting was held in southwestern Kansas, inside the HPO-HERO study area, and lasted 3 days. Activities mirrored those of the June all-hands meeting: updates from each HERO and HEROINE, discussion of future research plans, and a field trip of the HPO-HERO study area. Because the all-hands meeting was held in the HPO study area (which does not include Kansas State University, where the HPO team resides), videoconferencing was not

used to include team members who were unable to travel to the meeting. However, the meeting was very well attended by representatives from all HEROs and significant progress was made. The formal presentation and discussion sessions during the meeting focused on specific research topics and were designed to enhance and intensify cross-site collaboration in five crucial subjects: vulnerability, land use/cover change (LUCC), data and knowledge management, development and implementation of the HERO REU site, and cross-site comparison of the most historically significant human-environment interactions in each study area. This work resulted in the creation of four cross-site working groups, all of which have collaborated remotely since the all-hands meeting through collaboratory exercises and traditional methods.

The third all-hands meeting was held in Worcester, MA, on the Clark University campus, in May 2003. This meeting included a two-day writing workshop, plus a two-day series of presentations and discussions that included a field trip of the CM-HERO study area. During the two-day writing workshop, teams worked on developing cross-site comparative papers on vulnerability to drought, LUCC, data and knowledge management, historically significant human-environment interactions, and two papers from the summer 2003 REU site—one presenting a cross-site comparison of the research results (see below) and a second on the pedagogical approach of the REU site. During the second half of the meeting, the investigative teams first presented their progress and received feedback from the HERO team as a whole and then discussed plans for future collaborative research and products. This discussion included setting the focus for year 4, which is to establish more robust links among LUCC, vulnerability, and climate. As a result of the writing workshop, by the end of summer 2003, we expect to submit between seven and ten articles to various journals read by geographers and the human-environment, global environmental change, visualization, and geocomputation communities.

Intensification of cross-site collaboration marked advancement in the way HERO protocols are developed. For instance, the HERO vulnerability assessment protocol tested during REU activities in summer 2002 (see below) was developed at Penn State and then applied and tested at all four HEROs by the REU students and their faculty mentors—a top-down approach to protocol development. The results of that research include vulnerability assessments for all four HEROs, datasets detailing the spatial distribution of natural and technological hazards and vulnerable demographic groups, and two journal articles in preparation: one performing a cross-site comparison of vulnerability to natural and technological hazards, and a second on the pedagogy of involving undergraduates in collaborative human-environment research. While these products are significant achievements, one of the most important findings of the summer research is that the protocol was not entirely robust across all four study sites due to differences in scale and in the physiographic and demographic diversity among the sites. Consequently, the first of the HERO cross-site working groups was formed shortly after the completion of the REU research period to address shortcomings in the protocol. This vulnerability group instituted a new collaborative model of protocol development that involves an iterative consensus-building process—a bottom-up approach. This approach, discussed in more detail below, focuses on commonalities among the sites to ensure comparability, while allowing each site the flexibility it needs to retain the unique characteristics of each place in its analyses. Similar approaches were adopted by the other working groups formed during the October all-hands meeting.

The intensified cross-site collaboration was greatly enhanced by collaboratory exercises. As will be noted in the section on HEROINE activities, the collaboratory foci were e-Delphi, e-Notebook, and e-Conferencing. For e-Delphi, the HERO team participated in an intense exercise with two objectives. The first objective was to use the tool to reach consensus on the best way to

define and describe the concept of vulnerability to hydroclimatic change; the second was to test the latest version of the e-Delphi tool. From that exercise, the team decided to use the IPCC definition of vulnerability (see below) after an in-depth discussion of several alternatives. In addition, the e-Delphi tool developers continue to receive valuable experience in the Delphi process and feedback on how to improve the tool. The vulnerability working group was then charged with the task of developing a protocol to assess vulnerability under this unifying definition. The discussion of the HERO Meta-Protocol below describes how this activity fits into the overall protocol development process. The e-Notebook tool was used for data storage and retrieval for the first time during the summer REU project. The use of this tool enhanced the ability for HEROs to share data, both among sites and among researchers at the same site, but (as described in the HEROINE section) was not without its problems. This learning experience resulted in the development of the HERO knowledge management system, Codex, which will be used in summer 2003 to enhance and improve data management and dissemination and to track the evolution of HERO protocols and research. Finally, e-Conferencing played a central role in connecting researchers at all four HEROs. Video conferences have been held at regular intervals by the Vulnerability Working Group and the REU Planning Group and have been used for periodic all-hands meetings, connecting researchers working on all topics at all sites.

A third all-HERO activity is a series of panels, papers, and posters that was presented at the Annual Meeting of the Association of American Geographers in New Orleans in March 2003. At the 2002 AAG Meeting in Los Angeles, an illustrated paper session drew 50 non-HERO attendees into a 40-seat room, thus demonstrating strong interest in the project by the geography community. We drew a smaller, but engaged audience for our two-panel series this year. The first session presented advances in infrastructure development. The second session consisted of presentations on research currently being conducted at all four HEROs, as well as a presentation describing the summer REU program. In addition, undergraduate student participants of the REU program during summer 2002 presented posters and HERO investigators delivered several papers to organized sessions. HERO investigators also used the conference as a setting for ad-hoc working group meetings, particularly for advancing research and preparing for the May all-hands meeting and the summer REU work.

The fourth all-HERO activity concerned the ongoing commitment to undergraduate research through NSF's Research Experiences for Undergraduates (REU) program. In the last quarter of Year 1 and first three quarters of Year 2, the team hosted five REU students supported by five REU Supplements to HERO. These students became integral members of the project, producing important research and contributing both to the all-hands meetings and to the illustrated poster session in Los Angeles. Encouraged by the success of this activity, the HERO team applied for and received funding to conduct a formal HERO REU Site during the summer of Year 2. This innovative REU Site supported 12 undergraduates—three each from Massachusetts, Pennsylvania, Kansas, and Arizona. The program started with a two-week short course at Penn State, taught by the PI and a team of post docs and graduate students, at which the REU students learned basic theory and methods used in human-environment research. Laboratory and field methods received equal emphasis. At the end of the short course, mentors from all four HEROs flew to Penn State to meet the students, participated in an all-hands meeting that overlapped the last two days of the short course (thus integrating the REU students into the project and allowing them to meet many of the HERO investigators virtually, if not really), and escorted the students back to their HEROs. During the remaining six weeks of the HERO REU Site, students worked in three-person teams to conduct a vulnerability assessment of their study areas using the



vulnerability assessment protocol discussed in the 2002 Annual Report. Unique features of this REU Site are not only the distributed nature of the REU experience, but also the cross-site collaboration using the HERO collaboratory. For example, weekly e-Conferences allow the REU students to compare research experiences and to maintain ties with the rest of their cohort. In the end, the opportunity to host REU students has drawn the HERO team members closer through planning, interaction, and shared experience. It has accelerated the collaboratory development and provided additional motivation for protocol development. The experience from this past summer was so positive that the HERO project applied for and received funding from NSF to continue the HERO REU Site through summer 2005. During summer 2003, students will interview community water system managers and from this knowledge (with guidance from the faculty mentors) develop an index of water system vulnerability to climate (e.g. droughts and floods). The HEROINE tools will be used even more intensively this summer than it was last year because the students will use the new knowledge management tools (see below), which will enhance the ability of the students to communicate and share complex ideas and data sets across sites.

## HEROINE

HEROINE's aims are to develop computational infrastructure to support collaborative human-environment research and to assess the benefits of advanced collaboration tools for the research process. While the three original research areas within the HEROINE effort—collaboratory, data management, and geocomputation—have all received attention during Year 3, the focus of the HEROINE team's recent work has been on the convergence of these areas around a fourth component: the problem of knowledge management for the complex environmental sciences. This convergence will further integrate HEROINE's computational infrastructure with the proof-of-concept studies under way at the HERO sites. The following sections outline HEROINE's recent work in its four research areas.

### *Collaboratory*

The HERO Collaboratory is designed as a suite of integrated tools that take advantage of ubiquitous desktop networking technology to enable collaborative scientific exploration and decision-making by teams of distributed users. The four HERO sites are the primary users of the Collaboratory tools at present, although the tools are designed with broad user bases (and even applications beyond the study of human-environment interaction) in mind. Several of the HEROINE Collaboratory tools have attracted interest from groups unaffiliated with the HERO project, and we actively encourage their use by such groups.

**e-Delphi.** The Delphi method is an approach to group problem-solving appropriate for questions that require the estimates of a panel of experts. Through an iterative series of questions and feedback, a moderator guides participants toward a synthesis of group belief. For issues in human-environment relations, the Delphi method is a useful technique for gathering predictions on the drivers or effects of global change and choosing phenomena to monitor.

HERO e-Delphi (<http://hero.geog.psu.edu/eDelphi>), an asynchronous system that allows users to contribute at any time throughout the course of a Delphi activity, is a Web-based implementation of traditional mail Delphi surveys. The e-Delphi tool has undergone further

refinement during Year 3. Participants use a secure login to access a personalized e-Delphi start page from which they can enter current activities; participants can also start new Delphi activities and select a panel of new or existing users to invite. While HERO's e-Delphi tool is not the first computer-based Delphi system, it is the only one that is available to the public over the Internet. The e-Delphi system was designed to support human moderators by taking care of most managerial tasks (such as emailing reminders to participants, controlling the length or style of responses), allowing moderators to spend more time working with the participants. E-Delphi is also anonymous, removing many of the barriers to frank discussion (e.g., social status, personality) that accompany face-to-face meetings.

The summer 2002 REU students were the first large group to use the e-Delphi system and provided important feedback on early versions of the software. Several usability and backend improvements were made in response to their experiences; the first real test of the system came with its use in the fall by the Vulnerability Working Group. HERO's e-Delphi also allows outside users who visit through links from other sites or search engines (the HERO tool is one of the top listings on Google.com for online Delphi systems) to request access for their own groups. To date, over a dozen requests to use the tool have come from around the world, and many groups (in health and medicine, construction, and economics) are planning to include e-Delphi as part of their collaboration. While its use by external organizations helps spread HERO's message, the e-Delphi tools help collect usability information from users, allowing HEROINE researchers to improve understanding of the process of group decision and negotiation as well as the nature of communication supported by asynchronous technologies.

**e-Notebook.** Recognizing the importance of preserving a record of the process of scientific investigation, the e-Notebook system is designed as a Web portal to all of HERO's data resources, including working documents, plans, sketches, measurements, and more. While paper notebooks are common in the laboratory sciences, geographers and environmental scientists commonly keep the history of their ideas in tacit knowledge. By explicating their data, methods, and hypotheses, e-Notebook allows researchers not only to improve the efficiency of their own work (by having ready access to all of their past products), but to increase the effectiveness of collaboration. The e-Notebook permits other team members to have access to the records of analyses that have been performed in other places or at other times, thus allowing them to reuse data, replicate methods, or compare problem-solving strategies.

HEROINE's current e-Notebook implementation uses the Electronic Laboratory Notebook software developed at Pacific Northwest National Laboratories. This system involves a central server that manages individual notebooks, to which users connect using their Web browser coupled with a stand-alone application. Users can create their own notebooks as well as contribute to those for which a larger group is responsible. For example, each of the four HERO sites has its own notebook that it uses for storing local data (e.g., maps, census tables), meeting minutes, photographs, text documents, and audio or video files. Each of these files is annotated with contact information for the responsible investigator.

The e-Notebook served as the primary data distribution resource for the REU program and allowed students easy access to each other's data and documents. The system has also proved invaluable as a means of preserving project resources after the researchers who created them have moved on. There are a number of shortcomings in the current implementation, however, that have limited its usefulness and have prompted development of next-generation tools. First, the e-Notebook is organized around a hierarchical file structure that limits the flexibility users

have in viewing and storing information; a single structure applies to all users of a notebook, even though individuals might wish to customize the display of information to suit their needs or perspectives. Second, search functionality is limited, such that users must often browse through notebook pages looking for information, a search that is complicated by a potentially unfamiliar organizational scheme. Third, there is no effective way to create links between notebook elements that would help organize files around common themes (nor is there a way to even record the themes to which a file applies). Lastly, there is no means of preserving changes to the notebook that helps users (or HEROINE team members who study computer-supported work practices) summarize the development of individual or group reasoning. Because of these and other usability problems with the original e-Notebook, the adoption of the tool among HERO collaborators was not as great as it could have been. Based on the experience gained with the e-Notebook during Year 2, HEROINE researchers have been developing a new system from the ground up that better supports the work practices of those engaged in human-environment research. The section on Knowledge Management outlines this system.

**e-Conferencing.** The HEROINE Collaboratory aims to provide tools that support the range of collaborative activities required for truly global, integrative research. Both the e-Delphi and e-Notebook components of the Collaboratory are asynchronous, enabling researchers to connect with each other (and with each other's research products) at any time, and in any place, without requiring simultaneous interaction. There are times when face-to-face communication is necessary, however, because the efficient solution of problems hinges on synchronous dialogue. HEROINE's e-Conferencing solution provides desktop videoconferencing services to HERO sites, allowing spontaneous meetings between individuals or groups of HERO researchers. The e-Conferencing implementation also extends basic video communication with data sharing; researchers can use the conferencing system to explore data sets or give presentations collaboratively, viewing and even controlling the desktop of remote machines.

During Year 2, HEROINE deployed videoconferencing equipment to each of the four HERO sites. This equipment consists of an integrated camera and microphone unit, conferencing software, and (at Penn State) a Multipoint Conferencing Unit (time on which is offered by Penn State Information Technology Services) that brokers communication between the sites. To date, two all-hands meetings have been held using this equipment, demonstrating the feasibility of inexpensive substitutes for group travel. The sense of presence and fluidity of dialogue supported by integrated video and audio communication surpasses that afforded through audio-only (e.g., telephone) conferences. The REU students made extensive—almost daily—use of videoconferences, consulting about research methods and cross-site protocol development in real-time while located at their distributed research sites.

One of the most promising aspects of HEROINE's e-Conferencing system is the ability to send an auxiliary data signal in association with the voice and video streams. This facility offers two primary uses. First, users can broadcast any program on their machine, such as a presentation, to other participants in a conference. Second, a group of users can share control of a single machine, taking turns controlling the display of data in a Geographic Information System, for example, to support a point being made verbally. The integration of data sharing and conferencing streams mimics the same sort of informal discussions around a computer screen that might take place among researchers at the same location, but allows scientists anywhere in the world to participate. REU students used the data sharing capability to communicate problem-solving approaches they had developed. For instance, a student familiar with mapping

software used desktop sharing to allow another student to follow along as he explained a series of operations required to map Census data. The students then swapped control, so the “expert” student could watch as the other person attempted the same operations on her machine (and offered control of her desktop so the expert could help out as needed). Throughout, each participant of the videoconference could see (and hear) each other in a corner of their screens.

HEROINE’s research goals associated with the videoconferencing component of the Collaboratory include assessing how well electronic meetings substitute for face-to-face meetings. In particular, understanding how to tune the conferencing experience to produce the most productive replacement for same-place discussions will enable the HERO project to offer guidelines for the integration of conferencing tools into the research process.

### ***Databases***

During Year 3, HERO team members made extensive use of the data warehouses compiled during previous years. Much of the data and metadata that went into the vulnerability and land use change assessment products were derived from base sources contained in each HERO site’s local archive. REU students also contributed to these archives by submitting tabular and map data to these archives. It has become increasingly clear over the last year, however, that these data alone are insufficient to describe the true nature of human-environment interaction or of researchers’ investigation of this interaction. A stand-alone data store does not allow for the effective integration of data (which are but one component, and not always a necessary component, of the research process) with the collaborative tools that give these data contextual meaning. As a result, the data infrastructure effort has been rolled into the Knowledge Management task, discussed below.

### ***Geocomputation***

HEROINE team members continued to leverage resources from Penn State’s GeoVISTA Center to support the development and distribution of advanced computational and visual aids to exploratory data analysis. GeoVISTA *Studio*, the Center’s primary software product, provides a platform for the integration of software components developed at any HERO site. Moreover, researchers who use *Studio* can easily create and share small applications that include ready-made sets of data files and analysis tools. Thus, sharing a problem-solving strategy can be as simple as sharing a *Studio* application.

The component-oriented nature of *Studio* also allows its data analysis tools to be integrated into other applications. The Self-Organizing Map and Parallel Coordinate Plot components, for example, are currently being integrated with HEROINE’s e-Delphi system, bringing powerful concept visualization tools to Web-based discussions. Through this linkage of HEROINE and GeoVISTA resources, e-Delphi users can view concept maps that summarize the relationships between discussion topics and participants.

### ***Knowledge management***

The need to capture and share the rich record of the scientific investigation process has lead HEROINE researchers to work toward the convergence of several of its research streams under the theme of Knowledge Management. The data and other concrete research products that tools

such as the e-Notebook can store do not necessarily reflect how researchers conceive of a problem, what methods they used to explore the problem, and what outcomes resulted from their exploration. In an age of electronic science, rapid growth in the quantity and resolution of observations has not been matched by the development of computational representations of knowledge structures helping human analysts to classify and explain high-dimension data.

HEROINE's knowledge management activity concerns the development of tools that capture concept definitions as they evolve. These software components help meet the recognized need for interactive tools that can operate at the same levels of abstraction as their human users. Moreover, knowledge management tools that foster the integration of analyses across different researchers, different places, and different times are vital to fulfilling many of the goals of integrative complex environmental science. Assessing long-term climate trends, ecosystem change, carbon-cycle dynamics, and land-use change, for instance, require the integration of space-, surface- and laboratory-based measurements made in different places and of different quantities. Reconciling these measurements necessitates a semantics of environmental information, which this effort helps scientists create. HERO is also concerned with making current thinking available to future generations; is it possible to share not just data, but how these data guided our decisions (or how our decisions guided the collection of data)?

HEROINE's new knowledge management tool, tentatively called Codex, supports this spatial, temporal, and conceptual integration by creating a computational infrastructure that encodes concepts, thus allowing them to be defined, refined, and reused collectively by teams of collaborators. The applications for such a knowledge management system include:

- Revealing what data and methods are applied to problems (and at what stage they are applied), thereby guiding future data collection and tool development efforts.
- Comparing methodologies, concepts, and solutions with those of collaborators.
- Reusing or modifying existing methodologies or concepts to suit new problems, increasing problem-solving efficiency.
- Discovering core concepts that indicate levels of agreement within and between research domains.
- Describing the different perspectives—or worldviews—that inform how individual researchers approach problems.
- Maintaining an organizational knowledge base that archives the evolving state of institutional belief.

HEROINE has begun to implement a Web portal with a series of tools that allow researchers to encode conceptual information in an easy-to-use graphical interface. The core of this new system is a *concept representation* framework that stores concept definitions and relationships; this framework is built around the DAML (DARPA Agent Markup Language) notation that is commonly used to describe knowledge structures for the Semantic Web. *Concept capture* tools allow for both diagrammatic and form-based input; users can draw concept maps that are stored as concept definitions and can view the results of a concept or database query as a graphical network of relations. *Concept comparison* tools enable users to discover how similar concepts are constructed in different places, at different times, or by different people; it is also possible to compute levels of agreement among different versions of a concept to define the core elements that are shared among researchers.

The knowledge management system will play a critical role both for the students and the HEROINE investigators during the summer 2003 HERO REU Site. Students will have a suite of tools that help them explore their (and others') problem-solving approaches and link data and methods in digital experiments. The HEROINE team will gain a record of the knowledge structures that are built during the course of investigation, leading to an understanding of how environmental concepts are constructed, negotiated, adopted, revised, and retired.

## **The HEROs—Site Descriptions and Year 2 and 3 Activities**

### ***HERO for Central Massachusetts (HERO-CM)***

HERO-CM focuses its studies on Worcester County, Massachusetts. This county straddles the boundary between the northeastern United States megalopolis and rural New England and encompasses an area transitioning from an industrial to a post-industrial-service economy. As a result, growth in affluence and the population it attracts increases and changes the kind of land occupation in both urban and suburban settings. Urban settlement expands over abandoned, toxic industrial lands, while suburban settlement consumes forests and former agricultural lands for homes, open spaces, and roads. The impacts of these changes on ecosystems and human well-being are significant, independent of, and in concert with climate variation and change.

HERO-CM emphasizes the question, "How do six impacts of urbanization-suburbanization affect the exposure, sensitivity, and adaptive capacity of ecosystems and people in Central Massachusetts to climate variation and change?" The six impacts are:

- Fragmentation of the forests, threatening their composition and changing the carbon flux
- Increased exposure of the human population to animal-borne diseases
- Increased nitrogen loading to wetlands
- Increased surface runoff and reduced aquifer volume, decreasing well water supply
- Increased occupation on brownfields
- Enlarged disease vectors with increased nighttime temperatures regionally

Years 1 and 2 activities had three related components: constructing a historical database, developing a local Website, and individual and collaborative research on the HERO-CM research questions. These activities continued into Year 3.

In support of HERO-CM database development and research, the most important undertaking is the HERO-CM Fellowship Program—a competitive one-year program supporting several undergraduates who investigate human-environment problems in central Massachusetts. The program starts in summer by leading the fellows through a collective learning process, teaching them the fundamentals of HERO-related theory, methods, and problem construction. The program continues in fall with a two-semester directed research course in which each fellow develops an independent research project with a faculty advisor. A primary concern of the course is the creation of digital maps and associated metadata for the HERO-CM study area. By the end of spring, fellows generate maps with FGDC compliant metadata for several key physical dimensions, including land-cover, township boundaries, precipitation, and brownfields. All HERO fellows present their findings at the year-end Clark Academic Spree Day. Six fellows are participating in the 2002-2003 HERO-CM Fellowship Program; their results are presented in Section 4, "Project Findings."

Besides supervising HERO students' research, HERO-CM activities included ongoing work aimed at enhancing the ability to detect processes of landscape change from the statistical modeling of landscape patterns. Other research attempted to develop a theoretical framework that links the quantitative, positivist scientific paradigm with qualitative, alternative models of inquiry.

The beginning of Year 3 also saw an increase in interactive activities across HERO sites. In addition to participating in a sequence of videoconferences, HERO-CM personnel attended two HERO All-Hands Meetings held in June and October 2002, respectively. HERO-CM is taking the lead of coordinating cooperative effort within the Land-Use/Cover Change (LUCC) Group. A preliminary investigation on coping with droughts in the state of Massachusetts has been completed; the case study will be co-presented at the upcoming 2003 New Orleans AAG meeting in March as the first step toward a HERO collaborative journal article (with the other three HERO sites). Research findings on the history of central Massachusetts landscape change were compiled (discussed elsewhere). Participating in the HERO Data Group, HERO-CM is making contribution in several important ways, such as coordinating on-site data storage and organization, facilitating data sharing using the HEROINE collaboratory, and providing input to HERO data/metadata standard development.

Great effort was devoted to the infrastructural development at HERO-CM in Years 1 and 2. This effort continued in Year 3. The emerging local infrastructure at HERO-CM has two related components: (1) a geospatial database and (2) a local Website designed to support individual and collaborative research on the HERO-CM research questions and outreach. The improvement has revolved mainly around augmentation and reorganization of the data archive, enhancement of its user-friendliness, and upgrading the project Website.

Toward the end of fall 2002, fellows generated more maps with FGDC conforming metadata for several new key dimensions, including census data, elevation-slope-aspect data, digital maps of hydrographic features, surficial geology, as well as USGS gaging stations, and scanned images of the USGS topographic quadrangles for the entire state, a digital map of all roads in the state, a map of all viable habitats for endangered species in the state, and a map of all identifiable brownfields in Worcester.<sup>1</sup> Original data were created as well. For example, water samples were collected and recorded on data collection sheets. Maps of local water quality sampling sites were created. The five sampling sites of Tatnuck Brook Watershed were selected based on their accessibility and potential to serve as an indicator of the condition of the surrounding and preceding waters.

HERO fellows have also invested considerable time enhancing the user-friendliness of the data they created. One example is a computer program that enables the user to compile census data easily based on numbers, variables, and geographic regions. The program also offers a feature that allows the user to define new regions of study or to choose from several pre-determined study regions based on different HERO-CM study areas. Yet another example is a computer program which is able to read a map in the GIS software IDRISI and to arrange the output to show the breakdown of each land-use category within each town. Using this program to analyze information gathered from the HERO data archive, a potential user would be able to see where potential conflict between conservation groups and developers may occur.

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<sup>1</sup> See [http://www.clarku.edu/departments/hero/archive/DATA\\_DESCRIPTION.htm](http://www.clarku.edu/departments/hero/archive/DATA_DESCRIPTION.htm) for the recently updated data catalogue.

Over the past year, the HERO-CM Website experienced major enhancements. Interactive features are either in design or await activation, which will greatly enhance the utility of the site. The Website allows students to disseminate preliminary research findings. It also enables students to present their research in ways that enable the reader to relate research findings to data and references used in the analysis in a more tractable way. Students are also encouraged to report progress and notable events in their HERO endeavor on the Web, so that in the future they may use the Website to support their resumes.<sup>2</sup>

### ***Susquehanna River Basin (SRB-) HERO***

Although it is a rural landscape, the Susquehanna River Basin (SRB) has suffered intensive human use for more than two centuries. Three stages of lumbering—driven by demand for agricultural land, then fuel, and finally paper and other wood products—resulted in total deforestation of the basin by the early 20<sup>th</sup> century. Forest management has promoted significant regrowth in recent decades. Coal mining changed the cover of large portions of the basin and led to severe acid mine drainage in many of the basin's sub-watersheds. Transportation, first in the form of canals and later in the form of railroads and highways, transformed the land and opened the basin for settlement. Towns and small cities dot the basin today, but the surprisingly large rural population dominates the landscape. Agriculture flourishes in the valley bottoms and piedmont, from which nutrient runoff aggregates on its way to the Chesapeake Bay. Economic restructuring took place over the last few decades, replacing mining and the limited manufacturing base with high-tech and service-based enterprises. Urbanization and suburbanization is gobbling up prime farmland in dynamic growth poles, such as Centre County, although serious socioeconomic problems exist in many declining areas, such as contiguous Huntingdon and Clearfield Counties.

The long-range goal of the SRB-HERO is to engage this landscape of rich human-environment interactions by operating at multiple spatial and temporal scales. It will reconstruct LUCC history and its drivers and will model future LUCC to determine the present and future vulnerabilities of the basin's inhabitants to climate variation and change. It also will study carbon fluxes in the basin in an attempt to understand the contributions of the basin to climate forcing and the potential for managing the land to mitigate climate change. Spatially, it will be concerned with the effects on data and analysis of using both natural units (e.g., watersheds and ecoregions) and political units (e.g., townships and counties). It will compare data and analyses across small sub-basins (e.g., Spring Creek), large sub-basins (e.g., the West Branch of the Susquehanna), and the entire SRB. Temporally, it will address the effects caused by aggregating disparate data and processes by the units imposed by the daily, weekly, monthly, and annual calendars.

The SRB-HERO team is focusing its proof-of-concept activities on Centre County, a microcosm of the SRB. The county has experienced, is experiencing, and will experience: deforestation, forest regrowth, and intense forest management; coal mining and acid mine drainage; conventional American and traditional Amish agriculture; development of the transportation network; significant economic restructuring; rapid urbanization in the midst of a rural landscape; and significant socioeconomic disparities.

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<sup>2</sup> One good example is set by current HERO fellow Hua Wang; cf. her personal research Website listed at the bottom of page <http://www.clarku.edu/departments/hero/profile.shtml>.



Year 3 activities focused on the Upper Penns Creek Watershed, while continuing refinement of work on the Spring Creek Watershed from Years 1 and 2. The Spring Creek Watershed has an area of 146 km<sup>2</sup> and is the sub-basin in which Penn State is located. Despite its small size, it contains a diverse mix of logged and protected forests, mines, farmlands, non-farm rural homes, suburban communities, urban concentrations, and major institutions (i.e., Penn State and a state penitentiary). It presents a particularly relevant human-environment case study because not only is this area one of the most dynamic growth poles in Pennsylvania, but also the watershed is the site of a massive interstate highway project that is transforming the land cover and producing conditions that will encourage even more rapid development in the coming decades. Penns Creek Watershed is similar in size, but is significantly different in land use, demographic characteristics, and cultural composition. This watershed is used primarily for agriculture, mostly by Amish and Mennonite populations. Significant portions of the watershed are in, are entering, or are being considered for historical preservation and, therefore, can be expected to remain in agriculture for the near future. Nonetheless, forces from outside the watershed are driving significant land-use change, particularly demand for transportation linking the rapidly developing Spring Creek Watershed to the rest of the state. As construction plans are still being formulated, it is difficult to predict how this change may affect the watershed, but we continue to monitor this activity. During summer 2003, a vulnerability assessment was performed on the Upper Penns Creek Watershed; we are currently comparing this assessment with our assessment of Spring Creek Watershed. Further activities in Years 4 and 5 will focus on comparisons with adjacent sub-basins of similar size, but with varying biophysical attributes and socioeconomic contexts. This strategy will enable the SRB-HERO research team to perform cross-site comparisons within the county.

During Year 1, the SRB-HERO team worked on developing: (1) a historical baseline, (2) a conceptual model linking LUCC and climate variation and change, and (3) a vulnerability protocol based on the intersection of land-use and natural and technological hazards. Year 2 research focused on vulnerability assessment, land-use change, and carbon. Using the evolving vulnerability assessment protocol described elsewhere in this report, SRB-HERO investigators assessed the vulnerability of people and places in the Penns Creek Watershed to climate-related natural hazards and to technological hazards during Year 3. Research on LUCC took place at two spatial scales: Upper Penns Creek Watershed and Centre County. The Upper Penns Creek work focused on the vulnerability assessment, relating land use to the distribution of environmental hazards and socioeconomic groups. The Centre County research concentrated on LUCC over the period of satellite observations and resulted in complete LUCC maps that have been ground-truthed pixel by pixel. Carbon and greenhouse gas (GHG) inventories are also a focus of the SRB-HERO. Investigators have conducted GHG emissions inventories for Pennsylvania, five counties in central Pennsylvania (including Centre County), and the Penn State campus.<sup>3</sup> Updated inventories for Centre County and Penn State are underway, and a proposal to improve the recent inventory for Pennsylvania has been submitted to the Pennsylvania Department of Environmental Protection. HERO investigators also inventoried

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<sup>3</sup> GHG inventories are useful for many reasons (US Environmental Protection Agency, 2002. In Brief: The US Greenhouse Gas Inventory. A brochure accessed at <http://www.epa.gov/globalwarming/publications/emissions/ghgbrochure.pdf>). Scientists use inventories to understand those physical and human processes that first cause emissions and then respond to increased GHG concentrations in the atmosphere. Decision-makers use inventories to develop strategies and policies for emissions reductions and to track the progress of those policies. Regulatory agencies and corporations rely on inventories to establish compliance records. Businesses, the public, and other interest groups use inventories to understand the sources and trends in emissions.

Centre County carbon stocks as part of the LUCC research. See Section 2, “Project Findings” for details of the findings from these activities.

### ***High Plains-Ogallala (HPO-) HERO***

HPO-HERO focuses on a nineteen-county area in southwestern Kansas. Land cover has been significantly transformed in the study area by irrigation agriculture, extensive dryland cultivation, the development of mega-beef packing plants, and extraction of natural gas from the Hugoton gas field. Islands of population growth exist within a sea of long-term population decline. Local LUCC is a response to at least five major factors:

- Climate change (both interannual and longer-term variations)
- Agricultural and other policy changes
- Socioeconomic and demographic factors
- Resource availability (especially water resources)
- Local thinking, external influences, and decision-making

HPO-HERO is developing research protocols and data standards for mapping, monitoring, and explaining human-environment interactions in agricultural landscapes. Specific to southwestern Kansas, the research team places emphasis on natural resource issues such as groundwater depletion, technological innovation, farm policy, crop and animal prices, and agricultural restructuring. Methods are being designed to observe and record human response to climate change, stressing the themes of vulnerability, adaptation, and mitigation. HPO-HERO is developing methods for monitoring the impacts of human-induced climate change on the long-term economic, social, and demographic aspects associated with maintaining regional sustainability. It is clear that the local acceptance of global climate change is beginning to have tremendous implications for federal and state-level farm policy within the region. Investigations therefore will include how shifts in attitudes and beliefs about global warming influence the pattern of LUCC. Year 1 and Year 2 activities pursued these agenda items and included work on the HPO-HERO region’s historical database, the concept of vulnerability, and the impacts of endogenous agents of change in the study area.

Year 3 activities included work on LUCC and associated socioeconomic change, as well as on climate change, vulnerability, sustainability, and protocol development. Data collection and analysis continued on the changing spatial pattern and concentration of animal feeding operations, on the associated environmental attitudes and perceptions of feedlot operators, and on recent demographic changes demonstrating that the HPO-HERO region is representative of the entire Great Plains. This task is on-going. Data collection and analysis is resulting in manuscripts that document changes in feedlot agriculture and environmental attitudes and perceptions of feedlot operators and the spatial pattern/concentration of animal feeding operations, and demographic change for the 1990-2000 period that helps place the HPO-HERO region in a context that includes the entire Great Plains.

Given the HERO interest in land-use change in the face of climate variation and change, HPO-HERO researchers have worked collaboratively with colleagues at other HERO sites to develop Anderson Level 1 data that can be used in a change detection analysis. Supervised classifications of Landsat data from 1985 and 2001 have been performed for Gray County and delivered to the all-HERO LUCC group for comparative change detection analysis. The existing

literature on mapping CRP using satellite data has also been examined. Ongoing analyses of satellite data are determining LUCC associated with the Conservation Reserve Program in southwest Kansas based on multiple dates of imagery.

### ***Southwest and Mexico Border Region HERO (SOMBRHERO)***

The geographical extent of the SOMBRHERO study region is the United States/Mexico border region that divides southeastern Arizona (AZ), United States and northeast Sonora (SO), Mexico. The border runs through a diverse mix of environments ranging from fragile upland deserts to open grasslands and oak woodlands, to spruce-fir forests at elevations reaching 10,000 feet above sea level. Two transboundary river basins are situated in the region, the Santa Cruz River Basin and the San Pedro River Basin. Both rivers are distinctive because they flow south to north and, thus, Mexican land-use decisions influence United States water access and quality. The sister river basins fall within two counties on the Arizona side—Santa Cruz and Cochise—and three municipios on the Sonoran side—Nogales, Naco, and Santa Cruz. In addition, there are several major population centers, including Tucson, AZ, Nogales, AZ/SO, Cananea, SO and Hermosillo, SO.

The SOMBRHERO region is changing rapidly as NAFTA continues to rearrange economic relations towards open markets that encourage a dynamic border region. This dynamic makes the border region a particularly appropriate place to monitor and study local human-environment relationships because it exhibits different cultures, political institutions, resource management strategies, livelihood strategies, and socioeconomic processes—all of which operate at local scales but are influenced by globalizing forces. The study region also reflects the challenges embedded within transboundary environmental regimes that are increasingly positioned within globalized environmental issues.

More specifically, the region exhibits many problems associated with border industrialization including rapid urbanization, increased water and air pollution, poor or nonexistent sanitation infrastructure, and other problems associated with mounting traffic and migration flows. It also has a historical rural frontier presence that is particularly affected by and vulnerable to drought and land-cover change. On the American side, ranching exists on public and private rangeland, alongside mechanized agriculture and orchard farming of both large and small scales. On the Mexican side, most ranching is on ejido (common property) land, but with privatization, these lands are being parceled off and irrigated for intensive cropping (Figure 1). While these economic strategies may seem to be predominately rural, the linkages between urban and rural areas are increasingly important in evaluating human vulnerability, as well as environmental impacts. Moreover, the study region has a historically integrated resource economy based in mining that draws heavily on water sources, and exhibits some of the economic inequities and problems that recent border industrialization exemplifies.

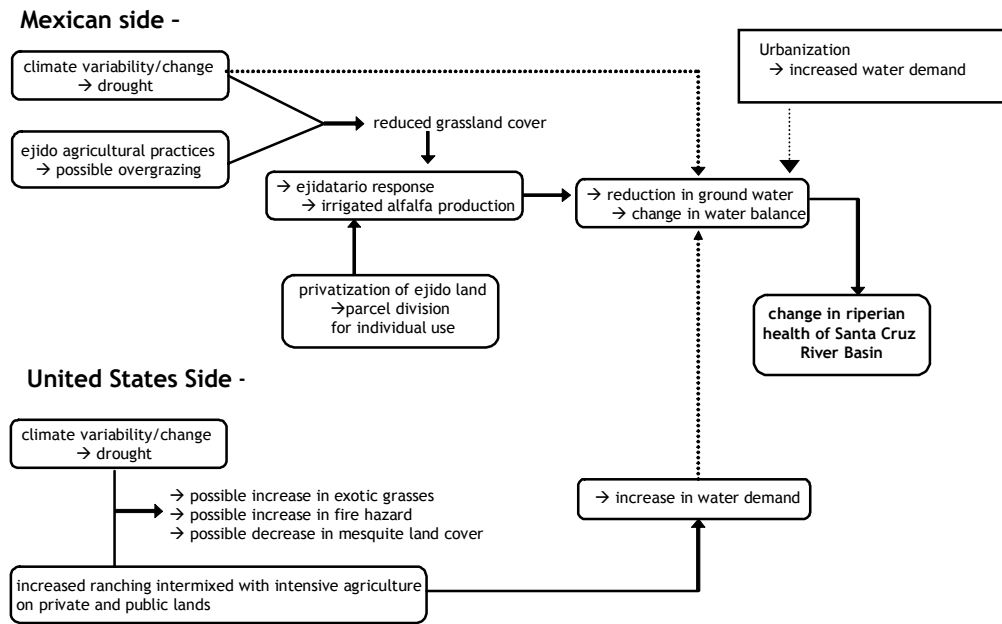


Figure 1: Problem definition for initial research on Upper Santa Cruz River Basin

Given this context, SOMBRHERO research draws from the following set of research questions:

- What are the major dynamics of LUCC and how do they reflect specific geographic patterns of land tenure, agricultural systems, mineral development, ecosystems, and urban change?
- How are larger forces of globalization and privatization (e.g., land and water reform in Mexico) influencing trends and patterns in land use and land cover?
- In what ways do climate variability and change, as influencing factors on ecosystems, shape both land cover and livelihoods that are dependent on this land cover?
- What are the social determinants and indicators of vulnerability to drought and other climate changes? How might new policies and technologies (e.g., seasonal forecasting and altered water institutions) foster adaptation?
- What linkages exist between rural and urban populations, and how do such linkages shift and/or influence vulnerability of people and landscapes to climate and environmental change?
- How are agricultural activities in response to climate change and variability, impacting riparian vegetation and water table balance in border watersheds?
- How has urbanization, in response to larger globalizing forces, affected water quantity, quality, and balance in border watersheds?

Year 3 research activities draw from tasks accomplished in Years 1 and 2, as well as represent collaboration with HERO researchers across study sites and expansion in research scope. Results are reported in Section 2 “Project Findings.”



## PROJECT FINDINGS

HERO is an infrastructure development project, so most of its “findings” are not typical of NSF-sponsored research. Given this caveat, the four strategies used to develop the HERO infrastructure—protocol development, intelligent networking, proof-of-concept, and network building—continued laying down a strong foundation for the infrastructure in Year 3. Note that network building is an outreach activity (reported in section 4, below) and as such cannot produce findings.

### Protocol Development

Two cornerstones of protocol development were continued: a meta-protocol and a vulnerability assessment protocol. In addition, based on the HERO meta-protocol, protocol development began on LUCC. Future protocol development for linking LUCC and vulnerability and for linking climate change to both phenomena is planned for Years 4 and 5. HERO has developed a meta-protocol; that is, a “protocol for building protocols.” Ideally, protocols should be well-structured, dynamic, and flexible. They should accommodate multiple criteria and should be multidisciplinary in scope. The HERO meta-protocol meets these standards by presenting four interactive phases of activity (Figure 2).

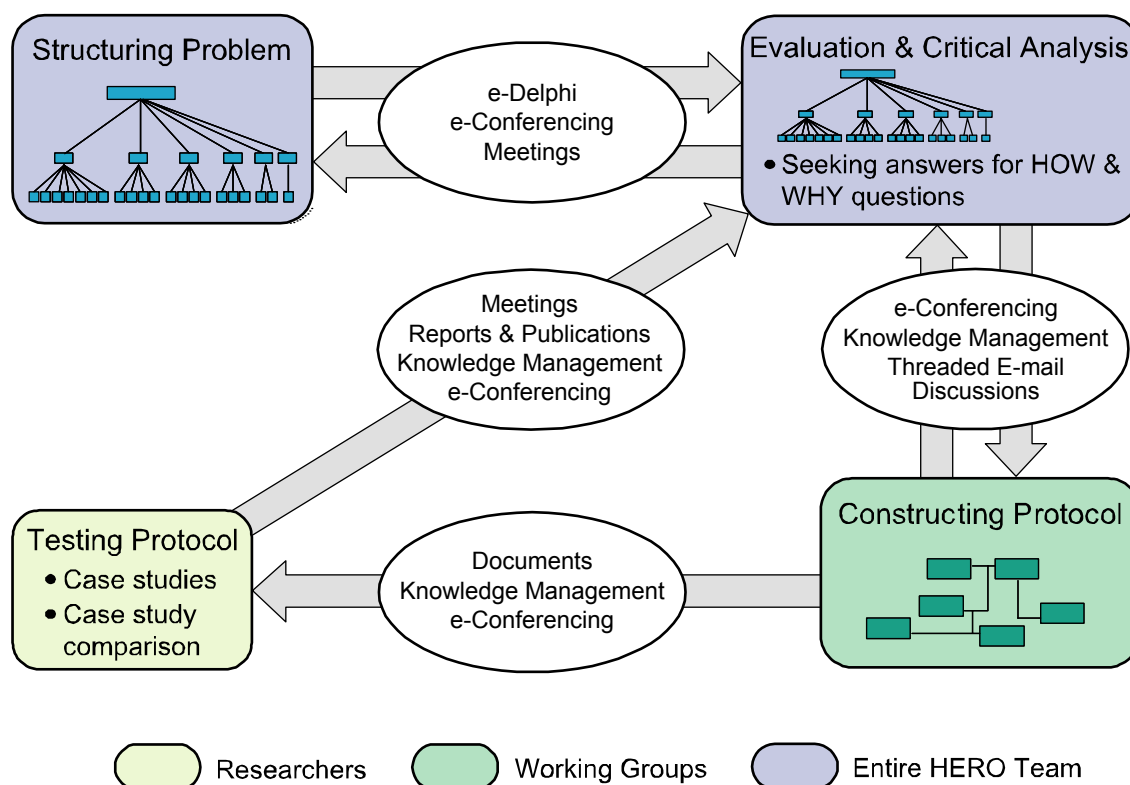


Figure 2. HERO meta-protocol framework

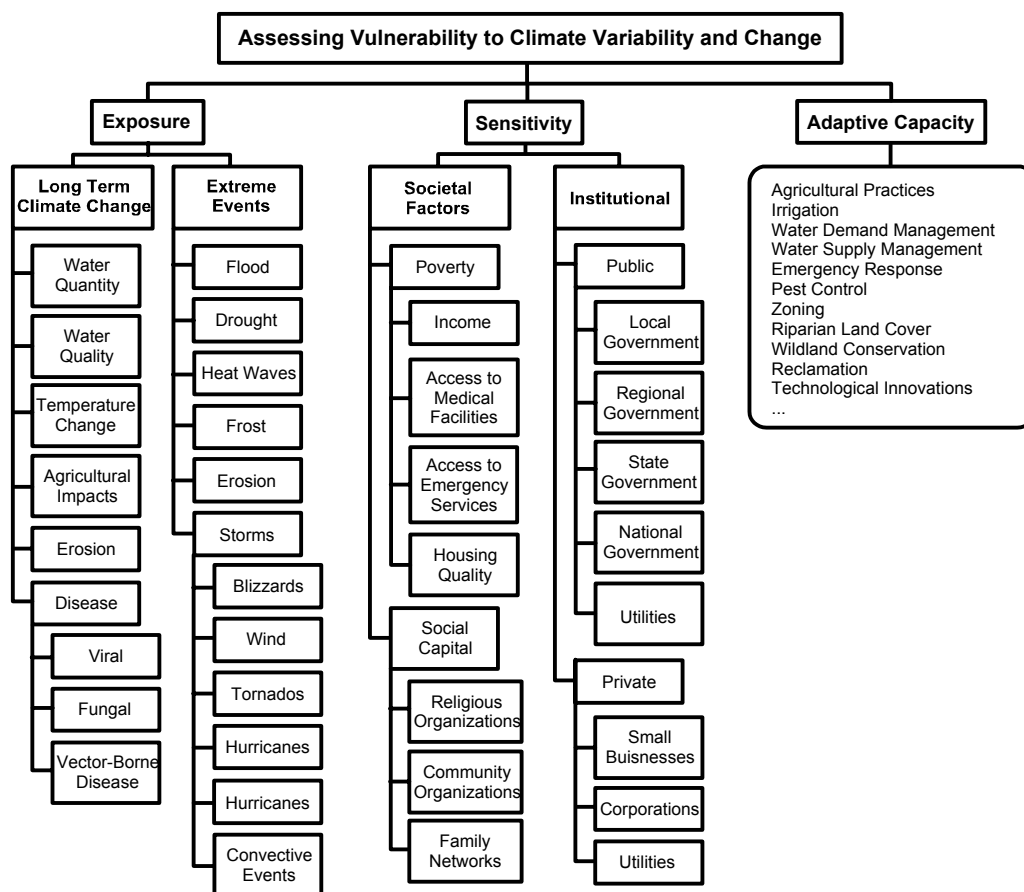
The meta-protocol framework is an iterative, flexible process that allows researchers to jump forward or backward from one phase to another at any time to address changing needs, knowledge, and technology. It is highly structured so that scientists can compare the framework at any two points in time, thereby seeing how their knowledge changed and improved. The framework facilitates collective efforts and consensus building; it allows different research groups and stakeholders to work together in an integrated process.

Two protocol-development activities involve the entire HERO team: Problem Structuring and Evaluation and Critical Analysis. Problem Structuring involves activities such as broadly defining terms, research questions, etc. Evaluation and Critical Analysis necessarily occurs at all stages of protocol development to ensure that the diverse expertise of the entire HERO team is utilized. However, to make the process of consensus building tractable, smaller groups are involved in actual protocol construction and testing. Protocol construction is done in cross-site working groups to ensure protocol elements are robust across all HERO sites and that the protocol is flexible enough to capture the uniqueness of each place. While the protocol is circulated among the entire HERO team for evaluation and critique, the final determination of the elements (topical foci, methods and data) of any protocol is made by the appropriate working group. Finally, the protocol is tested by researchers at all four sites—through meetings, reports, and HEROINE collaboratory activities—and is critically evaluated by the entire HERO team in preparation for the next iteration of the ongoing process.

HERO investigators started this process by applying a vulnerability assessment protocol—developed for contemporary coastal zones by NOAA’s Coastal Services Center on a theoretical foundation laid by Susan Cutter and colleagues at the University of South Carolina—to Cape May County, New Jersey. The investigators extended this protocol to a climate change context that included socioeconomic and LUCC change. The vulnerability assessment was able to demonstrate that, even with uncertainty concerning the number and strength of future coastal storms, sea-level rise will make wealthy residents much more physically vulnerable to storms while socioeconomically disadvantaged residents will be much more economically vulnerable to storms. The HERO investigators then moved the protocol inland to the Spring Creek watershed, Centre County, Pennsylvania. The researchers found that weather and climate do not currently pose particularly great risks to the population of the watershed, but that the combination of rapid urbanization and climate change will exacerbate those risks that do exist. In summer 2002, four three-person REU student teams applied the HERO vulnerability assessment protocol to the HERO-CM, HPO-HERO, and SOMBRHERO study areas, as well as to the Upper Penns Creek Watershed in central Pennsylvania, thereby facilitating further improvements to the protocol.

The latest iteration of the HERO vulnerability protocol is a result of two years of testing, constant re-evaluation, and critique. It attempts to provide guidance for the application of a set of standard methodologies aimed at evaluating the vulnerability of natural and social systems to both short-term climate variability and long-term climate change (Figure 3). Vulnerability is a function of exposure to various stressors caused by climate variability and change, the sensitivity of a system to these stressors (i.e., the degree to which a system will be affected adversely to a given degree of climate variability and change), and the ability of the system to adapt to these stressors (i.e., the degree to which adjustments in practices, processes, or structures can moderate or offset the potential for damage due to a given change in climate). Under this framework, a vulnerable system would be one that is sensitive to modest changes in climate, that has the potential for substantial harmful effects, and for which the ability to adapt is constrained. Hence, three main components of a HERO vulnerability protocol are exposure, sensitivity, and

adaptation potential. Two important additional issues that are important in a vulnerability assessment are uncertainty and links to all scales of policy. Such a comprehensive vulnerability assessment protocol is a dynamic, evolving product, rather than a static framework.



**Figure 3:** A hierarchical framework for a vulnerability assessment protocol

## Intelligent Networking

In Years 1 and 2, research on intelligent networking identified five system characteristics as important for supporting different-place (remote) collaboration:

- Facilitating dialogue—the ability to talk/chat while viewing and interacting with tools
- Group member behaviors—the ability to know what others were doing
- Drawing the group’s attention—the ability to indicate objects, places, and regions and to alert others to the indications
- Private work—the ability to work out ideas individually before sharing them with others
- Asynchronous collaboration—the ability to save and share sessions and to initiate new analysis from any point

In Year 3, HEROINE investigators built upon this foundation by applying these findings to development of remote collaboration tools and techniques detailed elsewhere in this report, including e-Delphi, e-Notebook, and e-Conferencing. (E-Delphi, e-Notebook, and e-Conferencing work in Year 3 was described in Section 1 of this report, “Project Activities.”) Thus, the main “findings” were the successful application of these five characteristics to the process of collaboratory.

## **Proof-of-Concept**

To be ready for testing the general HERO infrastructure—i.e., the protocols, data standards, and intelligent networking environment—the four HEROs continued building their local infrastructure. In addition, each site actively engaged in the continued development and testing of vulnerability and LUCC protocols. This section reports the results of the Year 3 activities documented in Section 1, “Project Activities” (and of necessity repeats some of that material for context).

### ***HERO for Central Massachusetts (HERO-CM)***

HERO-CM emphasizes the question, “How do six impacts of urbanization-suburbanization affect the exposure, sensitivity, and adaptive capacity of *ecosystems* and *people* in Central Massachusetts to climate variation and change?” The six impacts are:

- Fragmentation of the forests, threatening their composition and changing the carbon flux
- Increased nitrogen loading to wetlands
- Increased surface runoff and reduced aquifer volume, decreasing well water supply
- Increased occupation on brownfields
- Increased exposure of the human population to animal-borne diseases
- Enlarged disease vectors with increased nighttime temperatures regionally

So far, all but the last two impacts have been tackled to various extents by our student researchers. In Year 3, in addition to the vulnerability analysis collectively undertaken by REU students in the summer, HERO-CM undergraduate fellows focus on following human-environment problems facing central Massachusetts:

- GIS analysis of the water quality and hydrological conditions within the HERO-CM study area
- GIS mapping of potential “hot spots” of conflicts concerning land-use between the conservation groups and developers
- Comparison of land-use change models
- GIS-based economic and environmental analysis of the campus energy monitoring project
- Geography of brownfields

Data collection and analysis were central to the progress made by the HERO-CM team. The team designed of a sampling program and preliminary hydrological monitoring toward the aim of developing a long-term water monitoring program. To ensure consistency, care was taken to



select sites, develop sampling procedures, and set up infrastructure for discharge measurements. This work generated a paper that evaluated hydrological and biogeochemical processes needed to be considered when evaluating water quality.

Collection and analysis of LUCC data continued as well, resulting in several planned publications, presentations, software products, and theses. Plans are in place to digitize the 1951 land-use maps for the small study area and assist with the analysis of the data provided by the other HERO sites. This work will inform a paper comparing two common land-use change models, GEOMOD and a Markov/Cellular Automata model. These models will be compared based upon their performance at predicting land-use change and around Worcester, as compared to a model predicting zero change from the initial point. These models will also be run through a multiple validation program that will determine at what resolution the simulation performs better than the null model predicting zero change. An honors thesis is being written on the aforementioned development of the VBA program being used to help identify potential conflicts in land use, and the program is slated to be introduced into the GIS package IDRISI in the near future. As part of the campus energy monitoring project, the team is studying the relationship between energy efficiency and housing types of the New England area. Within this regional context, the team will conduct a cost-benefit analysis in spring on the energy system at Clark and explore models that are both economically and environmentally efficient, thus contributing to evolving work on GHG emissions. Several of the results from the aforementioned research will also be presented at the New Orleans AAG meeting and a session on Land Use Change Modeling at the Framing Land Use Dynamics taking place at Utrecht University, the Netherlands in April of 2003. The work on LUCC also has been invited to appear in a special issue of the International Journal of Geographic Information Science titled Spatial Modeling to Explore Land Use Dynamics. Finally, researchers at Clark lead the effort to produce a cross-site LUCC analysis for all four study sites. The results of this analysis represent an advance in methodological approaches to LUCC, and yielded some interesting results. One of the principle findings is that different driving forces behind LUCC in different study areas results in different kinds of change, with some study areas exhibiting essentially permanent changes in land use/cover (such as urbanization), and others exhibiting flexible and reversible changes to the landscape (such as changes in crop type and desert cover). One hypothesis by the LUCC researchers was that permanent land use/cover changes may affect vulnerability to climate change differently than flexible changes. Research in year 4 will focus on establishing these links in a way that carefully considers the various stressors and their related vulnerability in the context of differing types of LUCC.

### ***Susquehanna River Basin (SRB-) HERO***

Year 3 research focused on vulnerability assessment, land-use change, and carbon. Using the evolving vulnerability assessment protocol described earlier in this section, SRB-HERO investigators assessed the vulnerability of people and places in the Upper Penns Creek Watershed to climate-related natural hazards and to technological hazards. Specific findings include:

- Floodplain occupancy is minimal, so routine overbank floods are unlikely to result in significant property damage or loss of life.

- Because of its karst (limestone) landscape, the area is prone to flooding outside of floodplains, which can occur almost anywhere and can cause widespread, but typically minor damage to homes, businesses, and water supplies. Causes of this category of floods include inland-trekking tropical systems, mesoscale convective systems, and wintertime rain-on-snow events—all of which may increase with climate change.
- Most homes, businesses, and institutions are relatively impervious to drought because they rely on large and medium-sized community water systems fed by rich groundwater supplies. In contrast, small community water systems and private wells—which serve a relatively small proportion of the population—do suffer the effects of drought. If the watershed continues the current pattern of rapid population growth and urbanization, then the bigger community water systems will not withstand drought as easily as they do today. Droughts are expected to be an important feature of the region’s future climate.
- Other weather and climate-related hazards occasionally strike the watershed, including tornadoes, severe thunderstorms, blizzards, and ice storms. All are low-probability events with little spatial differentiation. A possible exception is wind-driven wildfires, which cause heavily forested developments to be vulnerable. Nevertheless, such fires are rare visitors to the area because of fire management.

While these findings are similar to the findings of last year’s study of Spring Creek, analysis of these two watersheds allows for a more detailed comparison, which is underway. This comparison also will be used to frame new research questions to enhance the vulnerability protocol during the next iteration of protocol development. This enhancement will likely focus on variations in sensitivity and adaptive capacity of the very different demographic groups in these watersheds. Further, the SRB-HERO will complete three more assessments of adjacent watersheds in the county during Years 4 and 5, all with very different physiographic and demographic characteristics, thus allowing the team to conduct cross-site comparisons within its own study area. This work, combined with cross-site comparisons with the other HEROs, will be the driving force behind development of the vulnerability protocol.

Research on LUCC took place at two spatial scales: Penns Creek watershed (which covers roughly 12% of the county) and Centre County. The Penns Creek work focused on the vulnerability assessment reported in the previous paragraph, relating land use to the distribution of environmental hazards and socioeconomic groups. The Centre County research concentrated on two topics. The first involved LUCC over the period of satellite observations. The results show that during the last third of the 20<sup>th</sup> century, there was virtually no change in the area of forested land (which covers 73% of the county) because forest regrowth balanced losses to urbanization and logging. Agricultural land (the second largest land cover at 19%) slowly lost ground to urbanization (the third largest land cover at 5%). Results also demonstrate the demise of coal mining in the county, with mine reclamation efforts changing the land cover from open-pit mines to grass and shrub. This work sets a baseline for future land-cover inventories, which will be increasingly important as major highway construction projects change Centre County from its relatively isolated status to a major transportation hub.

Carbon and greenhouse gas (GHG) inventories are becoming a focus of the SRB-HERO. The GHG inventories demonstrate the overwhelming contribution of carbon dioxide to local emissions, primarily from power generation and secondarily from transportation and buildings. In addition to the GHG inventories, HERO investigators inventoried Centre County carbon stocks as part of the LUCC work reported above. Although there is uncertainty in these

estimates because of uncertainty in the science, the single greatest reason for terrestrial carbon loss appears to be farmland conversion to urban lands. Although current rates of change are not great, future carbon stocks could deplete quickly with the rapid urbanization projected for the county. Both the GHG emissions and carbon inventories are amenable to monitoring and protocol development.

### ***High Plains-Ogallala (HPO-) HERO***

Year 3 activities included work on LUCC and associated socioeconomic change, as well as on climate change, vulnerability, sustainability, and protocol development. Land-cover change findings documented recent growth in the area devoted to both warm and cool season crops and a corresponding 20% decrease in the pasture/prairie land-cover type. Land Cover from several time periods maps have been provided to the CM-HERO team for a cross-site analysis on LUCC, which is ongoing. Data collection and analysis continued on the changing spatial pattern and concentration of animal feeding operations, on the associated environmental attitudes and perceptions of feedlot operators, and on recent demographic changes demonstrating that the HPO-HERO region is representative of the entire Great Plains. Regarding climate change, HPO-HERO investigators considered both the Holocene context of local environmental change and the application of Palmer's climate stability index for the Great Plains. Work on local vulnerability incorporated both biophysical and social aspects of vulnerability and concentrated on bioterrorism and the spread of animal diseases. For issues of sustainability, HPO-HERO scientists developed key questions for assessing long-term trends and transitions in sustainability. Ongoing work is examining and testing potential adaptation indexes and region-specific indicators (e.g., crop shifts associated with ground water depletion), while looking at adaptation corollaries in the mitigation literature regarding natural environmental change (e.g., drought) and socio-economic measures of resiliency as a surrogate measure of local adaptation potential.

The HPO-HERO hosted an All-Hands Meeting in the center of our study area and took responsibility for both assisting on local arrangements and developing a full-day field learning experience for team members from the other sites. The trip utilized the team's knowledge differences between southwest Kansas and other areas being addressed by HERO to 'show off' important aspects of the HPO-HERO region, while concentrating on the central HERO issues of landscape change and vulnerability. At the all-hands meeting, the HPO-HERO team took the lead in developing a list of major events that have shaped the local landscape. Based on this initial effort, the entire group decided to develop similar list of relevant events for the other HERO sites. This has recently been accomplished, and the HPO-HERO team is now working on comparing and contrasting the contributions from the four HERO sites as a foundation for a manuscript that will be written during the May 2003 All Hands Meeting.

Additional efforts during the past year addressed the Research Experience for Undergraduates (REU) program. The 19-county size of the study area presented problems that other HERO study teams did not deal with and a modification to the size of the area addressed will be likely for the 2003 effort. This issue also demonstrated the importance of scale, and the need to account for scale in protocol development. This continued as the REU students are getting a poster ready for the 2003 AAG Meeting.

### ***Southwest and Mexico Border Region HERO (SOMBRHERO)***

Year 3 research activities draw from tasks accomplished in Year 1 and 2, with focus on data analysis, write-up and submission of results, and collaboration with HERO researchers to compare findings across sites. Year 2 tasks evolved around: 1) data collection; 2) land use/cover change analysis; and 3) vulnerability survey testing and design. The following describes Year 3 progress.

The goal of the data acquisition and compilation are to maintain a digital library of data for analyzing and monitoring human-environment interactions in the study region, while insuring access of this database to researchers interested in borderlands issues. While many data sets have been successfully acquired, the search for data sources relevant to SOMBRHERO is ongoing. In Year 3, SOMBRHERO researchers began tasks to visualize these data sources in meaningful ways. A geography graduate student is now using SOMBRHERO data to develop geovisualization techniques for borderland issues related to environmental change. These techniques will be both web based and map oriented. In Year 3, sophisticated digital base maps were created for each of the river basins located within the SOMBRHERO site.. They include DEMs, other topographic information, population centers, rail and road transport networks, and riparian channels. This is no small task, considering the Mexican-US border context where data sources are at different resolutions, and are often only available in hardcopy. These maps are available on the newly updated SOMBRHERO website (see description below). Summer work will focus on making these maps interactive with socio-economic data. In addition, 2002 Summer Hero REU students used these data sources as base maps for a vulnerability assessment that tested pre-designed HERO protocols. The results of this work is a document available for download on the SOMBRHERO website and were presented by REU students at the annual Association of American Geographers meeting in March, 2003. An evaluation of the research process and results was presented at the Annual Association of American Geographers meeting in March, 2003. Results will also be used in a forthcoming paper evaluating vulnerability protocol effectiveness across the HERO sites. This paper will be one of the first cross site HERO collaborations in the HERO project.

A second outcome of the work involving data collection and compilation is an updated version of the SOMBRHERO website, located at <http://www.u.arizona.edu/~csorren/sombrhero>. Work is still in progress, but the website is much expanded to include the following: 1) information on our border environment education module for undergraduate classes; 2) information on our REU program with downloadable applications and past student reports; 3) information on current research findings, in particular, urbanization in Ambos Nogales using remote sensing, economic information on the Maquila Industry in Ambos Nogales, water consumption data on the Santa Cruz River Basin, and mapping dust pollution in Ambos Nogales; and 4) an updated study region section with digital base maps.

As part of their overall research on LULCC, SOMBRHERO investigators finished remote sensing accuracy assessment and analysis on land cover change in the Santa Cruz River Basin and on urban cover change in the border twin cities of Nogales, Sonora and Nogales, Arizona. Preliminary findings of land use cover change for the river basin were presented at the Annual Association of American Geographers Meeting, March 2002 by 2001 REU student. The analysis was then refined using ground truth information and will be used within a forthcoming paper on the major change events in the basin over that last 1 ½ centuries. In addition, the data was reclassified under the Anderson Land Use Cover Classification to be made compatible with other

HERO study sites and will be analyzed for a forthcoming HERO collaborative paper comparing drivers of land use cover change across sites. The Nogales work was presented at the Annual Association of American Geographers meeting, March 2002 and a manuscript is forthcoming. In addition, the Nogales land cover change work is being used as baseline information for new research looking into sources of dust pollution in the Nogales region. This work links data on dust pollution (PM10), precipitation and temperature, and traffic flows to dust cover source maps as derived from land use cover classifications and evaluates the change in potential dust pollution from 1985 onward, a period that is particularly interesting to SOMBRHERO as it covers the pre and post NAFTA period. The work leverages funding from the NASA Space Science Grant for Undergraduate Research, involves a former 2002 REU student, and a paper is expected to be forthcoming in summer 2003.

In Year 2, SOMBRHERO investigators began to develop survey instruments to refine the understanding and measurement of vulnerability in the study region. The main research questions driving the survey instrument development are: How does access to resources influence vulnerability of people to climate and environmental change? And, what local social indicators explain the differential vulnerability of people? Two surveys have been developed to address these questions—one oriented towards urban areas, the other, rural areas—and are now under Human Subjects review at the University of Arizona. Final revisions of the surveys are under Human Subjects review and summer 2003 fieldwork is planned in Ambos Nogales to understand the growth of colonia neighborhoods and their issues with access to water resources. In addition, to these site specific surveys, SOMBRHERO researchers are working in collaboration with HERO researchers across sites to refine a vulnerability protocol that specifically addresses drought in the HERO regions. Preliminary work was presented at the Annual meeting of the Association of Geographers in March 2003, and is currently being written up for submission.